JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOL. 25 MAY 15, 1935 No. 5

PHYSICS.—*What is electricity?*[1,2]

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I trust that there is no one so optimistic as to suppose that because I have asked this question I am going to answer it, nor so pessimistic as to fear that because I have asked a question which I cannot answer I can offer you nothing but platitudes. I believe it possible in this case to avoid both Scylla and Charybdis.

This question, said the late Professor John Trowbridge[3] of Harvard University, is often asked as though it were capable of a short and lucid answer which might be understood by any person of liberal education. Many answers have been given, but it is interesting to note that the more definite and confident the answer the older it is, and that as we ascend the ladder of time toward the present day such answers as we encounter are less definite and more cautious.

It will be interesting to review, perhaps rather briefly, the ideas which have been held at various times as to the nature of electricity, and then, looking over the wealth of physical discovery which has been amassed in the past forty years, to endeavor to select from it such facts as may be of importance in guiding and controlling future speculation on this question; for though such speculation has been at a minimum, if not a stand-still, during the twentieth century, it will doubtless revive again. Speculation, or as it has been otherwise termed: "apt conjecture, followed by careful verification," has been behind much of the advance of science. Such was the method of Faraday and of Darwin. The conjectures of the ancients, having little in the way of observed fact to guide them, might range far and wide, and had small heuristic value, but with the growth of experiment the range of conjecture has continually narrowed and its value as an aid to further progress has steadily increased.

[1] Publication approved by the Director of the National Bureau of Standards of the U.S. Department of Commerce. Received March 30, 1935.

[2] This is the fifth of the Joseph Henry Lectures of the Philosophical Society presented March 30, 1935, in honor of the first president of the Philosophical Society.

[3] TROWBRIDGE. *What is electricity?* London: Kegan Paul, Trench, Trubner and Co. 1897.

The beginning of our knowledge of electricity is lost in the mists of antiquity. What we can recover of it is excellently told by Park Benjamin in his history: *The intellectual rise in electricity*.[4] It is customary to credit Thales (600 B.C.) with the first observation of the attractive power of rubbed amber, but Benjamin shows that amber was widely known among the ancients for centuries before Thales. Beads of amber have been found in the ancient lake dwellings of Europe, in the royal tombs at Mycenae (2000 B.C.) and throughout northern Italy. The identity in chemical composition of these relics with the amber of the Baltic sea coast is significant of the esteem in which this substance was held and of the distance over which it was thought worth while to bring it. The golden glow of the polished beads suggested the beaming sun, called by Homer ἠλέκτωρ, which doubtless gave rise to the Greek name for amber, ἤλεκτρον.

It is incredible, as Benjamin points out, that this widespread acquaintance of the ancients with amber should have existed so long without its electrical property being often noticed. It is probable that Thales but shared the knowledge of his time in this respect, for his acquaintance with the things of Nature in general was such as to enable him to make the first recorded prediction of an eclipse of the sun. Thales left no writings of his own, and all we know of him we have learned from those who lived several centuries later.

It appears from these authorities that the ancients regarded electricity as a soul or spirit resident in an otherwise lifeless substance. This was in harmony with the prevailing thought of the times, which regarded all motion as evidence of life. The air was inanimate, but the wind was the breath of Aeolus; the waves of the sea were excited by the wrathful strokes of Neptune's trident; the lightning was the thunderbolt of Zeus. This animistic explanation of the nature of electricity was simple and definite enough to be understood by any one, and lasted for several millenniums, in fact until the revival of learning and the growth of experimental science supplied material upon which to base a rival theory.

We are helped to realize this animistic point of view when we read in a translator's footnote to Gilbert's book on *The Magnet*[5] that a certain ancient physician recommended the administration of doses of powdered lodestone in cases of estrangement between husbands and wives. Given the premises of the time, such a conclusion was perfectly logical. It was obvious that the patients exhibited a defi-

[4] London: Longmans, Green and Co. 1895.
[5] Translation by P. Fleury Mottelay. New York: John Wiley and Sons, 1893, p. 56.

ciency of a certain spiritual element which was found in the lodestone, and the administration of that medicine followed as naturally as a modern prescription of cod liver oil because of its vitamin content.

It was the middle of the sixteenth century before the next answer on record was given to the question: *What is electricity?* This answer came from Cardan,[6] whose name is familiar to mathematicians (perhaps more so than it deserves to be). Cardan was the originator of the fluid theory of electricity which held the stage in one form or another for over three centuries, and survives to-day in popular parlance in the term *the electric fluid* or, still more colloquially, *the juice.* Cardan passed from the spiritual to the material in his explanation, which was that amber "has a fatty and glutinous humor which, being emitted, the dry object desiring to absorb it is moved towards its source, like fire to its pasture; and since the amber is strongly rubbed, it draws the more because of its heat."[7]

In this last sentence we see the influence of Cardan's profession. He was, among other things, a physician, and was accustomed to warm the cupping glass in drawing blood from his patients. The laws of pneumatics were not yet understood at that time, and it was generally supposed that the cupping glass acted because of its heat.

The fact that this *fatty and glutinous humor* was intangible and invisible seems to have caused Cardan no embarrassment. We may perhaps view this the more charitably when we think of the contradictory attributes that later scientists have found it convenient to assign to the luminiferous ether.

The year 1551 in which Cardan published this theory may be taken as marking the end of the first era, in which electricity was regarded as a soul or spirit. Its beginning goes back beyond recorded history.

The concept of electricity as a material substance contained in certain bodies known as electrics was strengthened by the experiments of Gilbert (1600), who showed that many substances besides amber were to be included in this class, but the full development of the fluid theory of electricity did not come until the middle of the eighteenth century. In the meantime, von Guericke (1672) had invented his sulphur globe electrical machine, which made electrical experimentation easy on a large scale. With the facilities thus placed at his disposal he discovered electrical conduction and electrostatic repulsion, the latter destined to be a phenomenon of prime importance in later speculation on the nature of electricity.

[6] CARDAN. *De subtilitate*, lib. XXI, Paris. 1551.
[7] PARK BENJAMIN, op. cit. p. 248.

In the eighteenth century development of the fluid theory two names are prominent, those of Du Fay and Franklin, each typifying a separate trend in theory.

Du Fay's experiments (1733 and later) chronologically preceded those of Franklin. His most important discovery was that glass when rubbed behaved in one respect quite differently from amber; a bit of gold leaf excited by contact with the glass tube is then repelled by the glass but attracted by excited amber. "And this," said Du Fay, "leads me to conclude that there are perhaps two different electricities." These he distinguished accordingly as vitreous and resinous, and laid down the law that like electricities repeal each other and unlike attract.

To explain the same phenomenon Franklin (1747) postulated a single electric fluid of which all bodies were normally full. If a body acquired more than this normal amount he called it *plus*, or positively electrified, and if its charge was less than normal, *minus*, or negatively electrified.

Franklin's hypothesis had simplicity in its favor; it required one less assumption than that of Du Fay. In this respect it obeyed more closely the rule laid down by Newton: "We are to admit no more causes of natural things, than such as are both true and sufficient to explain their appearances . . . for Nature is pleas'd with simplicity and affects not the pomp of superfluous causes."[8]

This simplicity of Franklin's hypothesis, added to the reputation which he himself rapidly attained in scientific circles, gave the one-fluid theory an advantage over its competitor for the time being, but a serious theoretical objection was soon raised against it. Since on this theory a negative charge meant a deficiency of electric fluid, there must be a limiting value of negative charge, namely when the body is completely emptied of the electric fluid; but two such bodies, both being negatively charged, should repel each other—and why?

There was much hesitancy on the part of the one-fluid advocates about pushing this argument to its logical conclusion. It remained for a bold German named Aepinus (1759) to seize the bull by the horns and assert that matter devoid of electricity is self-repellent.

This doctrine came as a shock to a generation many of whom could remember Newton. It was useless to point out that Newton had deduced the law of gravitation by observation of bodies that possessed their normal amount of electricity, and that the behavior of matter with the maximum negative charge was something which no

[8] NEWTON. *Principia*, Book III: *Rules of reasoning in philosophy.*

one had ever observed. The one-fluid theory had received a serious jolt from which it never recovered; this argument was used against it as late as the 1830's. The attention of theoretical physicists of the eighteenth century was turned toward the two-fluid theory, and during the closing years of that century and the early part of the nineteenth the work of Coulomb, Laplace, Biot and Poisson produced an elaborate and elegant mathematical theory which so well described all the electrostatic phenomena then known that by 1830 the two-fluid theory was generally accepted.

But it often happens that as soon as one theory is comfortably settled on the throne another rises up to challenge its supremacy. We shall see the reign of each successive theory of electricity growing shorter. The thousands of years of the first era were followed by three centuries of the second. In the first half of the nineteenth century great things were happening. In 1820 Oersted had discovered that an electric current could produce a magnetic effect, thus tying together what had previously been regarded as separate phenomena. In 1822 Seebeck showed that electricity could be generated by heat. These discoveries impressed themselves on the mind of Faraday, then at work in the Royal Institution. He was familiar with the work of Davy in producing chemical decomposition by electricity, and the converse phenomenon of Volta, the production of electricity by chemical action. Faraday was also aware of the converse of Seebeck's discovery, the production of heat (and light) in the electric arc, and his thoughts turned naturally toward the undiscovered converse of the Oersted effect. He says himself at a later time[9] (1845):

"I have long held an opinion, almost amounting to conviction, in common I believe with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, into one another, and possess equivalents of power in their action. In modern times the proofs of their convertibility have been accumulated to a very considerable extent, and a commencement made of the determination of their equivalent forces."

Such were the considerations which led Faraday to attempt the generation of electricity by means of a magnet (1831). The story is familiar to all of us; how he placed a magnet in a helix of wire and found that no current was produced except momentarily while the magnet was being placed in or taken out of the coil. This discovery seems to have made quite an impression in other than scientific circles, as is evidenced by some verse which has come down to us:

[9] FARADAY. *Experimental researches in electricity*, 3: 1. London, 1855.

"Around the magnet, Faraday
Is sure that Volta's lightnings play.
To bring them out was his desire.
He took a lesson from the heart;
'Tis when we meet, 'tis when we part,
Breaks forth the hid electric fire."

Encouraged by this success, Faraday later (1845) sought and found a correlation between magnetism and light. Twenty years later this in its turn furnished the inspiration for Maxwell's electromagnetic theory, by means of which the domain of optics was annexed to that of electricity.

The publication of Maxwell's paper in 1865 may be considered as closing the second era of electrical theory, that in which electricity was regarded as a material fluid, and the opening of the third era in which the concept of electricity assumed a less material and more elusive form.

By 1865 the two great doctrines of nineteenth century physics, the conservation of energy and the correlation of physical forces (as foreshadowed by Faraday) had been enunciated and were well on the way to general acceptance. During the seventies and early eighties, electricity, in common with heat and light, was sometimes called, in the phrase of the day, *a mode of motion*, which meant a form of energy.

The adoption of this view was, of course, a matter of slow growth. Maxwell's electromagnetic theory had a long struggle for acceptance, so long, in fact, that Maxwell himself did not live to see its final triumph. He died in 1879, and it was not until 1886, when Hertz produced experimentally the electromagnetic waves which Maxwell's theory demanded, that its acceptance may be said to have become complete.

Against this concept of electricity as a *mode of motion*, that is to say, a form of energy, Lodge[10] in 1889 entered a protest. He pointed out that water or air under pressure or in motion represents energy, but that we do not therefore deny them to be forms of matter. He emphasized an important distinction between two terms: *electrification*, which is truly a form of energy, as it can be created and destroyed by an act of work, and *electricity*, of which none is ever created or destroyed, it being simply moved and strained like matter. No one, said Lodge, ever exhibited a trace of positive electricity without there being somewhere in its immediate neighborhood an equal quantity of the negative variety.

[10] LODGE. *Modern views of electricity*, p. 7. London, Macmillan and Co., 1889.

Lodge did much to crystallize the ideas of the time concerning the nature of electricity. These ideas, since Maxwell's merger of optics with electricity, had been, as Lodge pointed out, not clearly defined, but in general the idea was that electricity was in some way a phenomenon of the ether. Lodge enlarged upon this idea, explaining electrostatic phenomena as due to ether stress, electric currents as ether flow and magnetism as ether vortices. Electricity, which had been previously regarded as a material fluid, now became an immaterial one, and in consequence this third period of electrical theory may be called the ethereal era.

As we mount toward the present time we see the different eras of electrical theory rapidly shortening in duration. While the spiritual era lasted several milleniums and the fluid theory three centuries, the ethereal era lasted only a few decades. The fourth era is that which is still with us. It may be called the atomic or quantum period, in which it is noteworthy that but little attention has been paid to the ultimate nature of electricity and a great deal to its structure. It is difficult to say when this period began, as, in fact, the ethereal era began to die almost as soon as it began to live.

Wilhelm Weber,[11] in 1871, in developing his theory of magnetism, pictured to himself light positive charges rotating about heavy negative ones, much like a satellite about a planet; and in 1874 Johnstone Stoney read before Section A of the British Association a paper entitled: *The physical units of nature*, which was not printed until seven years later.[12] In this paper he asserted the atomic nature of electricity and made a rough calculation of the elementary charge on the basis of Faraday's law of electrolysis. Ten years later[13] he was the first to use the term *electron*.

Helmholtz,[14] in his Faraday lecture at the Royal Institution in 1881, further developed this line of thought, saying (p. 290): "Now the most startling result of Faraday's law is perhaps this. If we accept the hypothesis that the elementary substances are composed of atoms, we cannot avoid concluding that electricity also, positive as well as negative, is divided into definite elementary portions, which behave like atoms of electricity."

Maxwell himself saw that his electromagnetic theory was essentially continuous in its nature, and recognized the difficulty arising from the implications of Faraday's experiments. In his *Treatise on*

[11] MILLIKAN. *The Electron* (2nd edition) p. 20. University of Chicago Press. 1924.
[12] STONEY. Phil. Mag. 11: 381–390. 1881.
[13] STONEY. Sci. Trans. Royal Dublin Society, 11th series, IV: 563. 1891.
[14] HELMHOLTZ. Journ. Chem. Soc. (London) 39: 277–304. 1881.

electricity and magnetism (1: 313. Chap. IV. 1873), in the chapter on electrolysis he says: "It is extremely improbable that when we come to understand the true nature of electrolysis we shall retain in any form the theory of molecular charges."

For Helmholtz, however, the atomic nature of electricity was beyond question. Electricity, as he saw it, was a special chemical element[15] whose atoms combine with those of other elements to form ions. Moreover, it appeared to be a monovalent element, for it seemed that a monovalent element combined with one electron, a bivalent one with two, and so on, exactly as a chlorine atom combines with one atom of hydrogen and an oxygen atom with two atoms of hydrogen. Helium, with its zero valence and double electrical charge, was as yet unknown.

The inevitable process of reconciliation of these contradictory theories was early begun by Lorentz,[16] who suggested for this purpose his electron theory of electricity. On this theory all the effects of electricity inside bodies were explained on the assumption of electrons, and all the effects of electricity at a distance, electrostatic, electromagnetic and inductive, required the help of the ether. To unite these two classes of phenomena he assumed that each electron was closely bound up with the ether, and that any change in configuration of the electrons produced a change in the ether which was propagated with the velocity of light, and thus produced action at a distance.

About this time an entirely new line of experimental research was developing which was destined eventually to make the atomic concept of electricity dominant for a time. This was the study of the electric discharge in high vacua. Several workers had investigated this field without attracting much notice, but it remained for Crookes to direct widespread attention to this class of phenomena by an exhibition of novel and beautiful effects in vacuum tubes which he gave at the meeting of the British Association at Sheffield in 1879. Crookes unquestioningly assumed these effects to be due to electrified molecules of residual gas in the tube. It was shown later by others (J. J. Thomson, Townsend, Wilson, Millikan) that the negatively charged particles in a Crookes tube were not molecules or even atoms, but bodies of a minuteness previously unknown, about the 1/1800th part of a hydrogen atom in mass, and bearing a definite negative

[15] GRAETZ. *Recent Developments in Atomic Theory.* London, Methuen and Co. 1923.

[16] LORENTZ. Verslagen en Mededeelingen der Koninklijke Akademie van Wetenschappen, Amsterdam, 8: 323–327. 1891. Also Archives Neérlandaises, 25: p. 432, Chap. IV. 1892.

charge of electricity. For these tiny bodies the term electron, introduced by Stoney, was revived. Still later work brought to light the proton, with an equivalent positive charge but larger mass than the electron and, in our own day, the positive electron.

As the result of this new line of investigation it became clear that a great many electrical phenomena required the atomic theory of electricity for their explanation. A great many, but not all; for a large number refused to fall in line under a corpuscular explanation, but could be simply and completely explained on Maxwell's theory as ether disturbances. The discovery by Hertz of the electromagnetic waves predicted by Maxwell did much to swing the pendulum back in this direction. The reconciliation of these contending views has been carried on much along the line originally taken by Lorentz. It is of interest to note that his idea of an electron inseparably bound up with the ether is found today in all essentials in the theory of wave mechanics.

We have now brought this somewhat hurried survey of electrical history up to the present day. We have seen that past speculations as to the nature of electricity fall into four classes, each corresponding to an era of thought. In the first of these eras, beginning probably with the earliest observations of electrical attraction, and terminating in the middle of the sixteenth century, electricity was regarded as a soul or spirit. The second era may be said to have been opened by Cardan in 1551 and closed by Maxwell in 1865. During these three centuries electricity was regarded as a material fluid of one or two kinds. It is worthy of note that during this period the concept of the electrical fluid showed a trend toward the immaterial, from Cardan's *fatty and glutinous humor* to the impalpable and imponderable fluid of the early nineteenth century. In the third era electricity in its various manifestations was regarded as some kind of an ether disturbance of a continuous nature. The fourth concept emphasized the atomic or discontinuous structure of electricity without any suggestion as to the ultimate nature of these atoms.

But though speculation as to the ultimate nature of electricity has been in abeyance since the opening of the twentieth century it will certainly arise again, and within limits it is well that it should. We may therefore turn now to an examination of the wealth of material which the last forty years have placed at our disposal and see what it may contain that is likely to be of importance in guiding and suggesting future speculation as to the nature of electricity.

The emphasis laid by the twentieth century on the structure rather

than the nature of electricity is natural, for structure is much more easily determined than nature, and moreover a knowledge of the first is likely to give us some useful hints as to the second. It appears that the discontinuous structure of electricity goes almost hand in hand with that of matter. A tabular view of the known elementary particles of matter with their associated charges of electricity will be useful.

CHARGE	+	−	0
MASS: HEAVY	PROTON	...	NEUTRON
MASS: LIGHT	+ELECTRON	−ELECTRON	(NEUTRINO)

The heavy particles now known, the proton and the neutron, have a mass equal to that of a hydrogen atom; the light particles have about 1/1800 of this mass. The light neutral particle has not yet been discovered, but so urgent is the demand for it in current nuclear theory that it has been named before its advent.

According to the idea that has prevailed for two centuries, positive and negative electricity should be merely reflected images of each other, their properties being equal and opposite. The behavior of the negative electron and the proton shows nothing inconsistent with this concept as far as electrical properties go. On the discovery of the positive electron it was at first thought that it was shorter lived, or as a chemist might say, more reactive than its negative counterpart, but this has not been borne out by subsequent investigation.[17] The mass associated with the positive charge in this case has been investigated by several persons. The latest work is that of E. Rupp[18] who finds that the mass is within five per cent of that of the negative electron. Rupp appears to have found one point of difference between the two which, if confirmed, will be of importance.

It has been found that the passage of negative electrons through thin films of metal is accompanied by a diffraction effect, photographs of the electron beam after transmission showing a series of concentric rings. Rupp passed negative and positive electrons through the same films of gold and aluminum, and found that while the negative particles gave the usual rings the positive particles showed a continuous scattering. We will return to the interpretation of this later.

As to the neutron, it is still uncertain whether it is a proton which has acquired a negative electron or whether it is to be regarded as an independent entity without electric charge. The latter, as we shall

[17] Allowing for relative abundance.

[18] RUPP. Physikal. Zeit. 35: 999. 1934. But in Zeit. f. Physik. 93: 278. 1935, Rupp has withdrawn his earlier article for further verification.

see later, would be in serious conflict with present accepted electrical theory.

There was a time, not so very long ago, when the atom of matter was considered to be its ultimate structural unit. The discovery of the proton and the electron gave meaning to the term *sub-atomic*. With this in mind, the question naturally arises as to a possible further subdivision of the electron. Several observers have claimed to have found evidence of smaller charges than that carried by the electron, but Millikan,[19] after an exhaustive discussion of the subject, came to the conclusion that up to 1924 there had been adduced no satisfactory evidence of this smaller charge.

In the early years of the present century there was some discussion as to whether the electron was to be regarded in shape as a rigid sphere (Abraham) or as contractile. The latter hypothesis was advanced by Lorentz to explain the negative result of the Michelson-Morely experiment. Lorentz supposed the electron, by motion through the ether, to flatten into an oblate spheroid. Experiments by Bucherer[20] in 1909 were interpreted as favoring the hypothesis of Lorentz.

But in 1927 a new line of experimental evidence as to the structure of the electron was opened up by Davisson and Germer,[21] soon followed by G. P. Thomson.[22] These investigators found in brief, that electrons (of the negative variety) might be scattered by reflection or diffracted by passage through very thin films of metal in such a way as to suggest that an electron is at least as much like a little bunch of waves as it is like a particle, and that neither aspect can be ignored.

This is well brought out by G. P. Thomson's diffraction rings. The electron must have a wave aspect, or there would be no interference pattern; it must have a charged particle aspect, or the whole ring system would not be deflected by a magnet, as it is found to be. The whole situation, in fact, had been foreshadowed theoretically by the wave mechanics of de Broglie and Schrödinger.

A number of explanations have been offered for this dual behavior. Perhaps the most completely worked out is that of J. J. Thomson,[23] based upon the diffraction rings obtained by his son, which lend themselves particularly well to theoretical treatment. On this view the electron is associated with and accompanied by a group of waves

[19] *The electron*, Chap. VIII.
[20] BUCHERER. Annalen der Physik **28**: 513; **29**: 1063. 1909.
[21] DAVISSON and GERMER. Phys. Rev. **30**: 705. 1927.
[22] G. P. THOMSON. Proc. Roy. Soc. **117**: 600. 1928.
[23] J. J. THOMSON. *Beyond the electron*. Cambridge University Press. 1928; Phil. Mag. **6**: 1254. 1928.

which guide and direct its motion. Now it was found by a study of the speed of the electrons and the associated wave lengths in the diffraction rings that a curious and complicated relation existed between these quantities. If u is the velocity of an electron and λ its associated wave length, this relation is:

$$\frac{u\lambda}{\sqrt{1-u^2/c^2}} = C \qquad (1)$$

in which c is the velocity of light and C is a constant.

But this, as J. J. Thomson shows, is exactly the relation that should hold for the group speed of electromagnetic waves in a medium such as the Kennelly-Heaviside layer, containing a multitude of electric charges, positive and negative.

J. J. Thomson therefore suggests the following structure for the negative electron:

I. A nucleus which, like the older concept of the electron, is a charge of negative electricity concentrated in a small sphere.

II. This nucleus does not constitute the whole of the electron. Surrounding it there is a structure of much larger dimensions which may be called the sphere of the electron. This sphere contains an equal number of positive and negative charges, forming a little Kennelly-Heaviside layer around the nucleus. Measurements on the diffraction rings indicate a diameter for this sphere at least 10,000 times that previously accepted as the diameter of the electron.

III. The nucleus is the center of a group of waves and moves with the group speed in its atmosphere of electric charges.

At the time that J. J. Thomson proposed this hypothesis the positive electron was not known. Here comes in the importance of Rupp's work[16] previously referred to. On their face, these experiments indicate either that the train of waves that accompanies a negative electron is absent from the positive electron, or that all possible wave lengths are present.

Just as the atom, once regarded as an ultimate structural unit, is now recognized as a complex of electrons, protons, neutrons and possibly neutrinos, so the electron, it seems, must be regarded as a similar complex. Much more, doubtless, is to be learned about its structure before we can hope to answer the question: *What is electricity?*

Perhaps the most outstanding fact in modern physical theory is the dominant position occupied by electricity. In the nineteenth century one spoke of matter and electricity as two separate and in-

dependent entities; nowadays electricity has become the fundamental entity of which matter is merely an aspect. Matter, once supreme, has lost its individuality and has become merely an electrical phenomenon which electricity may exhibit more or less according to circumstances.

It is obvious that our answer to the question: *What is electricity?* will be fundamentally influenced according to whether we hold an electrical theory of matter or a material theory of electricity. It will therefore be worth our while to examine the foundation for the present view that electricity, whatever it may be, is the sole world-stuff. So radical has been this change in our thinking that it would seem a foregone conclusion that it must be based upon the clearest and most unequivocal of experimental evidence.

This change in our concepts did not come suddenly. Its beginning dates back to 1893, when J. J. Thomson[24] showed on theoretical grounds that a charged sphere in motion through the ether would encounter a resistance which to all intents and purposes would appear as an increase in the sphere's inertia, i.e., in its mass. Calculation indicated that this effect would become appreciable only if the velocity of the charged body was comparable to that of light.

In 1893 this suggestion was of academic interest only, no bodies moving with sufficient speed being then available for experiment. A few years later conditions had changed. The study of radioactive substances and of the discharge of electricity through gases had placed at our disposal positively and negatively charged particles moving with unprecedented speeds, which in the case of the negative particles were in some cases comparable with the speed of light. Here, it would seem, was an opportunity to test Thomson's theory of increasing mass.

Unfortunately, the conditions of the problem were such that it was not at first possible to obtain a measure of the mass of such a particle, but only a determination of the ratio of the electric charge to the mass which carried it (e/m).

Kaufmann[25] found, however, that for the swifter particles this ratio was less than for the slower ones. There were only two ways of explaining this fact, both equally radical: either the mass increased or the charge diminished as the speed of the particle became greater.

In this dilemma opinion inclined generally to the first alternative,

[24] J. J. THOMSON. *Recent researches in electricity and magnetism*, p. 21. Oxford, Clarendon Press. 1893.

[25] KAUFMANN. Gesell. Wiss. Göttingen, Nov. 8, 1901; July 26, 1902; March 7, 1903.

largely because there was in existence a theoretical reason to expect it, while no one as yet had been ingenious enough to suggest any reason why a moving charge should alter. It is of importance to note that Kaufmann's experimental result, because of its equivocal character, cannot be accepted as more than half proving J. J. Thomson's theory.

Kaufman calculated that such particles as he experimented with might have, when moving slowly, an *electrical mass* equal to about one fourth their total mass. In making this calculation he assumed that a particle behaved as though it were a little metallic conductor, but he was careful to point out that a different assumption might lead to another result.

J. J. Thomson, on the assumption that a particle had no metallic conductivity, but acted like a point charge, found that Kaufmann's results indicated that the whole of the mass of the particle might be accounted for electrically.

This was the origin of the electrical theory of matter. Its pedigree goes back to J. J. Thomson's theory, which in turn was derived from the electromagnetic theory of Maxwell. Kaufmann's experiments only half proved Thomson's theory, which in addition was complicated by a special assumption with regard to the distribution of the charge on the particle. Without this assumption only a part of the mass could be accounted for electrically.

But much water has run under the bridge since 1893. Forty years is a long life for any physical theory in these days, and the recent discovery of the neutron has brought with it a challenge to the electrical theory of matter.

In J. J. Thomson's original theory of the increase in mass of a moving charge it was an essential point that the lines of force should be free to adjust themselves as the motion demanded. As a leaf or a card tends to flutter down through the air broadside on, so the lines of force, originally distributed radially and symmetrically about the charge at rest, will tend to set themselves in a plane perpendicular to the direction of motion of the charge. They will not all be able to lie in this plane because of their mutual repulsion, but the density of the lines will be a maximum in this plane and a minimum in the direction of motion, and a certain space distribution will result, of such a nature that the apparent increase of mass can be completely accounted for.

But it is essential for this result that the lines of force shall be perfectly free at their outer ends; in other words, only a single isolated

charge is considered. Now in a structure like the hydrogen atom, composed of a negative and a positive particle, there is bound to be some interference with this freedom of adjustment. In a neutral, non-ionized atom it would appear that all of the lines must begin and end within the atomic structure.

J. J. Thomson must be given credit for foreseeing this difficulty, though the Bohr atom was as yet years in the future. He had an atomic concept of his own in mind at that early date, and pointed out that the distance between the particles constituting an atom must be thousands of times the diameter of a particle. In consequence, he said, almost all of the mass will originate where the lines have their greatest density, near each particle; and the particles are relatively so far from each other that the parts of the lines of force in their immediate neighborhood will have almost perfect freedom of orientation with the motion of the atom.[26]

This is a quantitative question; but it is clear that only under the most favorable conditions will we have a freedom of motion in the atom which approximates that around an isolated charge, and in consequence the electrical explanation of matter, on J. J. Thomson's theory, must be in the same degree approximate.

With the neutron, conditions are more rigid. Assuming the neutron to consist of a proton and a negative electron, the union of these must be almost as close as possible, as the neutron, on modern theory, may form a constituent of an atomic nucleus. Here we are dealing not with atomic magnitudes but with sub-atomic dimensions, which is quite another thing. Freedom of motion of the lines of force in such a structure must be almost non-existent. And if we make the alternative assumption that the neutron is an independent, non-electrical entity, the electrical theory of matter must admit of an important exception.

But an electrical theory of matter to be acceptable must admit of no exceptions. It must obey the *all or none principle*. If it is approximate in even the slightest degree, we are confronted with the existence of two kinds of matter, ordinary and electrical, and we are violating the rule of simplicity in reasoning laid down by Newton.

But has there not been later evidence supporting this theory?

It has sometimes been said that Millikan's oil-drop experiments, by which he measured the charge on a single electron, prove the constancy of this charge, and hence the variability of the mass alone in Kaufmann's experiments. It is true that Millikan found that the charge on an ion *after it had been transferred to the oil-drop* was the

[26] J. J. THOMSON. *Electricity and matter*, p. 51. New York: Scribner's. 1904.

same whatever the source of the original charge. Ions of different gases, unquestionably of different speeds, gave the same charge to the drop. But it is to be remembered that the measurement of this charge was made, not at the speed of the ion, but at that of the oil-drop, which was of the order of a few hundredths of a centimeter per second.

The special theory of relativity is sometimes quoted in support of the constant charge and variable mass. It is true that Einstein[27] in his original paper of 1905 gives a formula for the change of mass with the speed of a moving electron, which, like J. J. Thomson's formula, becomes infinite at the speed of light, and that he gives no similar formula for a change in the charge. It will be interesting for us to see how he obtained this result.

In section 10 of his paper Einstein derives the following formula for the x-component of the acceleration of a moving charged particle, together with formulas for the other components:

$$\frac{d^2x}{dt^2} = \frac{e}{m}\frac{1}{\beta^3}X$$

in which e is the charge on the particle, m its rest mass, X the component of the electric vector and β the familiar $1\sqrt{1-v^2/c^2}$.

It is evident that the quantity e/m is altered by the factor $1/\beta^3$, but whether the charge or the mass or both are changed is not obvious. Einstein without comment assumes e to be constant and m to bear the full effect of the modifying factor, and on this basis derives his formula for the change of mass.

This assumption, of course, was orthodox in 1905, but it is of interest to note that as a matter of logic the electrical theory of matter can claim no supporting evidence from the special theory of relativity.

On the basis of this result of Einstein's, Sommerfeld[28] introduced a modification into Bohr's theory of the atom. On Bohr's theory the hydrogen atom was regarded as consisting of a negative electron revolving in a Keplerian ellipse around a positively charged nucleus, the attraction between the two charges being balanced by the centrifugal force of the revolving electron. Sommerfeld (page 45) makes the orthodox assumption that the electrical charges remain constant, but that the mass of the revolving electron varies with its speed according to Einstein's formula. In consequence the mass of the electron fluctuates as it describes its orbit, being greatest at perihelion and least

[27] EINSTEIN. Ann. d. Physik 17: 891. 1905.
[28] SOMMERFELD. Ann. d. Physik 51: 1. 1916.

at aphelion, and its centrifugal force will vary slightly from that in a non-relativistic Keplerian ellipse. Because of this the orbit becomes an ellipse with a moving perihelion, like that of the planet Mercury. The effect of this will be to split up the spectral lines, producing what Sommerfeld called the relativistic fine structure.

This predicted effect has actually been found in the spectra of hydrogen and helium, the number of the component lines and their relative separation being in accordance with theory.

As to the value of this result as a confirmation of the electrical theory of matter, it is to be observed that Sommerfeld would have obtained exactly the same modification of the Keplerian ellipse if he had assumed the charge to decrease and the mass to remain constant, thereby disturbing the balance by reducing the centripetal attraction instead of increasing the centrifugal force.

The logic of the whole situation is that the electrical theory of matter can claim no independent support from Millikan, Einstein or Sommerfeld. It rests for the present on J. J. Thomson's theory, and even this theory assumes tacitly that the charge is unaltered by the motion. It is remarkable that every one we have mentioned, from J. J. Thomson onward, when confronted with the necessity of making a choice, prefers to keep the charge constant and let the mass take the consequences, and this without comment or apology.

Of course, there must be a reason for this; and although it is explicitly stated by no writer that I have seen, the reason is doubtless to be found in a fundamental law of electricity, that of the conservation of electrical charge, with its corollary, the exact equivalence of positive and negative electricity. This law states that no one has ever produced the slightest trace of a positive charge without the simultaneous production of an equal and opposite negative charge somewhere in the neighborhood.

This law has been the subject of some very searching experiments. We may operate within a large conducting cube, such as was built by Faraday at the Royal Institution; perform within it all the usual electrical experiments, excite a glass tube by rubbing it with fur, draw sparks from an electrical machine, and yet a sensitive gold leaf electroscope connected to the cube will remain undisturbed. It seems impossible to create or destroy an electric charge without a compensating creation or destruction of an equivalent charge of the opposite sign.

And yet the era of thought which has not hesitated to question the conservation of energy can hardly be expected to respect this elec-

trical principle; and in fact this law has been brought under fire from several quarters. If these points of order are sustained they will have an important bearing on future answers to the question: *What is electricity?*

It is well to remember in this connection that all the experiments upon which is based the law of conservation of electric charge have started with neutral bodies. The glass tube and the fur were at first neutral, but exhibited equal and opposite charges after being rubbed together; the electrical machine was at first neutral, but on being operated its two sides became equally and oppositely charged.

Suppose a chemist should announce that as a result of the analysis of several thousand neutral salts he had come to the conclusion that acid and basic radicals existed in equal amounts in nature; we would likely think him ignorant of such syntheses as that of the acid radical cyanogen (CN) from its elements in the electric arc. But is there any known electrical analogue of such a synthesis or its reverse dissociation? No, nothing that we have so far been able to produce in the laboratory; yet if we imagine some race of children of the gods who could play with planets as we with pith balls, something of this kind might come to their notice.

Among the phenomena of atmospheric electricity there is an unsolved mystery. Many fruitless attempts have been made to explain it consistently with the principle of conservation of electrical charge. Continual failure has led more than one physicist to look for the explanation in a slight departure from this principle, and it has been shown that a departure so slight as to be beyond laboratory detection would yet, on the large scale, solve this mystery. The difficulty in question is to account for the negative charge of the earth.

Our earth is not a neutral body. Its entire surface is negatively charged to such an amount that there exists near the surface a potential gradient of 150 volts per meter. The conductivity of the atmosphere is small, but not zero; and because of this conductivity and the potential gradient there is a continual conduction of negative electricity away from the earth amounting, over the whole surface of the earth, to a current of about 1000 amperes. Small as this may appear, it is sufficient to bring about a loss of 90 per cent of the earth's charge in ten minutes if there were no means of replenishing the loss. The nature of this replenishment is the mystery referred to.

So great has been the difficulty of accounting for this replenishment that in 1916 G. C. Simpson,[29] now Director of the British

[29] G. C. Simpson. Monthly Weather Review 44: 121. 1916.

Meteorological Office, raised the question of a possible spontaneous production of a negative charge in the earth's interior, but offered no suggestion as to how this could be brought into line with existing theory.

In 1926 Swann,[30] who had worked unsuccessfully with the same problem, followed Simpson's lead, but chose the other alternative of a slight annihilation, or as he called it, death of positive electricity. He was able to bring this into connection with existing electrical theory by generalizing Maxwell's equations. His fundamental idea was that there might be a very slight difference in the properties and behavior of the two electricities. Here again we are reminded of the difference apparently found by Rupp.

Such a suggestion was not without precedent. Lorentz[31] in 1900 had postulated a difference between the attraction of unlike charges and the repulsion of like charges to account for another mystery—gravitation. It must be admitted that the accepted idea of the absolute equivalence and mirror-image character of the two electricities had weakened somewhat when such men as the Director of the British Meteorological Office, the Director of the Bartol Research Foundation and a Nobel prizeman could join in expressing doubt of its accuracy.[32]

Swann's theory of the maintenance of the earth's charge is, from the theoretical point of view, the most successful that has yet been advanced. He modifies the equations of Maxwell by introducing two small terms, amounting respectively to one part in 10^{26} and five parts in 10^{19} of the main term of the classical theory. These additional terms involve the acceleration and time rate of change of positive charge.

Swann assumed no similar terms for the negative charge, his idea being that there is a slight differential effect in behavior. For simplicity, therefore, he introduced a differential term applying only to positive electricity. This assumption enabled him to account for a slow death of positive electricity due to the centripetal acceleration produced by the earth's rotation.

To account for the known electrical facts, there is necessary an annihilation of less than one proton per cc per day, equivalent to a loss of 0.5 per cent of the earth's mass in 10^{20} years. This would also account for as much of the earth's magnetic field as is symmetrical

[30] SWANN. Jour. Frank. Inst. 201: 143. 1926. Phil. Mag. 3: 1088. 1927.
[31] LORENTZ. Koninklijke Akademie van Wetenschappen te Amsterdam, Proceedings of the Section of Sciences 2: 559. 1900.
[32] Additional references: MORE. Phil. Mag. 21, 196. 1911. GLEICH. Ann. d. Physik 83: 247. 1927. W. ANDERSON. Ibid. 85: 404. 1928. A. PRESS. Phil. Mag. 14: 758. 1932.

about the earth's axis, and would give the correct ratio for the magnetic fields of the earth and the sun. Moreover no development of charge or magnetic field could be detected with a sphere of laboratory size rotating at the highest practicable speed. And finally, Swann's scheme is consistent with the special theory of relativity.

Whatever may be thought of Swann's fundamental assumption, it must be admitted that his theory is experiment-proof. Moreover, even though it should be definitely disproved, it would have the lasting merit of impressing upon us caution in extrapolating laboratory results to the cosmic scale.

The relations of newly discovered fact and existing theory are, as we have seen in this somewhat brief survey, rich in suggestion. Speculation is not dead, but sleeping. If the past is still an indication of the future, it will awake again to renewed activity, and when this occurs we will need a wide acquaintance with fact and a good sense of perspective to guide and direct future speculation on the question: *What is electricity?*

CHEMISTRY.—*3, 4-Dimethoxy-5-chlorocinnamic acid and some of its esters.*[1] RAYMOND M. HANN, Laboratory of J. P. Wetherill, Washington, D. C. (Communicated by GEORGE S. JAMIESON.)

The present communication reports the extension of the study of derivatives of 5-chloroveratric aldehyde (3, 4-dimethoxy-5-chlorobenzaldehyde) to include the synthesis of 3, 4-dimethoxy-5-chlorocinnamic acid. The new acid was prepared by condensation of the aldehyde with malonic acid in the presence of pyridine and piperidine according to the Knoevenagel reaction, the intermediate 3, 4-dimethoxy-5-chlorobenzalmalonic acid losing carbon dioxide during the reaction process to yield the desired substituted cinnamic acid. The acid was characterized by preparation of several of its esters.

EXPERIMENTAL

3, 4-Dimethoxy-5-chlorocinnamic acid.—A solution of 10 grams of 5-chloroveratric aldehyde and 13 g of malonic acid in 10 cc of pyridine was treated with 5 drops of piperidine and heated for one and one-half hours on the steam bath under a reflux, carbon dioxide being copiously evolved. The reaction was completed by refluxing for 15 minutes, the reaction mixture cooled, and treated with 15 cc of concentrated hydrochloric acid in 85 cc of water. The precipitated yellow

[1] Received February 18, 1935.

oil rapidly solidified, and after standing overnight in the ice box it was filtered and dried. Yield 12.0 g, quantitative.

The acid may be recrystallized from water or 50% ethyl alcohol, separating in ball-like clusters of gelatinous needles, but it is preferable to dissolve it in 10 parts of ether, then concentrate to about half volume, when upon standing it separates in colorless glistening prisms melting at 126–7° C (corr.) to a clear oil.

Anal. Calcd. for $C_{11}H_{11}O_4Cl$: C, 54.4; H, 4.6. Neutralization equivalent, 242. Found: C, 54.2; H, 4.7. Neutralization equivalent, 241.

Methyl 3, 4-dimethoxy-5-chlorocinnamate.—One g of 3, 4-dimethoxy-5-chlorocinnamic acid, 10 cc of absolute methyl alcohol and 1 cc of concentrated sulfuric acid were refluxed for four hours, the solution cooled, and the ester precipitated as an oil by addition of 50 cc of water. On standing it crystallized, and upon recrystallization from 10 parts of 80% methyl alcohol was obtained in colorless needles melting at 63° C (corr.). Yield 2.0 g, 95% of theory.

Anal. Calcd. for $C_{12}H_{13}O_4Cl$: Cl, 13.8. Saponification equivalent, 256. Found: Cl, 13.8. Saponification equivalent, 251.

Ethyl 3, 4-dimethoxy-5-chlorocinnamate.—The ethyl ester was obtained by the general procedure used for the methyl homologue. It crystallizes from 50% alcohol in colorless glistening prisms melting at 165° C (corr.) to a clear colorless oil.

Anal. Calcd. for $C_{13}H_{15}O_4Cl$: Cl, 13.1. Saponification equivalent, 271. Found: Cl, 13.0. Saponification equivalent, 265.

Phenacyl 3, 4-dimethoxy-5-chlorocinnamate.—One gram of acid was dissolved in 10 cc of 95% alcohol and titrated with N sodium hydroxide to phenolphthalein alkalinity (4.3 cc), then 0.1 g of acid (to prevent formation of phenacyl alcohol) and 1.0 g of ω-bromo acetophenone in 10 cc 95% alcohol were added and the reaction mixture refluxed for one hour. On cooling the phenacyl ester separated and was recrystallized from 40 cc of 95% alcohol, being obtained in glistening, colorless needles melting at 132° C (corr.).

Anal. Calcd. for $C_{19}H_{17}O_5Cl$: Cl, 9.8. Found: Cl, 10.0.

p-Fluorophenacyl 3, 4-dimethoxy-5-chlorocinnamate.—A solution of the sodium salt of the acid prepared as outlined for the phenacyl ester and 0.7 gram of p-fluoro-ω-chloro acetophenone[2] were refluxed for one hour. The fluorinated phenacyl ester crystallized from alcohol in ball-like clusters of long, colorless needles, and melted at 135° C.

Anal. Calcd. for $C_{19}H_{16}O_5ClF$: Cl, 9.4. Found: Cl, 9.2.

[2] Hann and Wetherill, This JOURNAL, 24: 526. 1934.

p-Chlorophenacyl 3,4-dimethoxy-5-chlorocinnamate.—This ester was prepared by the same general method from p-chloro-ω-bromoacetophenone and crystallized from 40 parts of boiling 95% alcohol in fine, glistening needles melting at 137° C (corr.) to a clear oil.

Anal. Calcd. for $C_{19}H_{16}O_5Cl_2$: Cl, 17.9. Found: Cl, 17.8.

p-Bromophenacyl 3,4-dimethoxy-5-chlorocinnamate.—This ester crystallizes in long, colorless acicular needles melting at 132° C (corr.) to a clear oil.

Anal. Calcd. for $C_{19}H_{16}O_5ClBr$: Saponification equivalent, 439. Found: 437.

SUMMARY

3,4-Dimethoxy-5-chlorocinnamic acid and its methyl, ethyl, phenacyl, p-fluorophenacyl, p-chlorophenacyl, and p-bromophenacyl esters have been synthesized and described.

GEOLOGY.—*Outliers of the Tuscaloosa formation on the western highland rim of Tennessee.*[1] KENDALL E. BORN, Washington University, St. Louis, Mo. (Communicated by ROLAND W. BROWN.)

During the summer of 1933, while mapping the areal geology of Dickson County in the western Highland Rim area of Tennessee, several patches of unrecorded water-worn gravels were noted capping some of the higher hills and interstream areas. These gravels undoubtedly represent remnants of the Tuscaloosa formation of Upper Cretaceous age, which formerly overlay the Highland Rim plateau. The present paper calls attention to these newly recognized occurrences since most of them are farther east than any areas of the formation previously mapped.

The term Tuscaloosa was first applied by Smith and Johnson[2] to the basal Upper Cretaceous deposits in the vicinity of Tuscaloosa, Alabama. In western Alabama and Mississippi the Tuscaloosa, consisting of irregularly bedded clays, sands, and gravels, has an estimated thickness of approximately 1,000 feet. The formation becomes more gravelly toward the north and was formerly considered to thin out in the vicinity of the Alabama-Tennessee line. The presence of this Upper Cretaceous formation on the western Highland Rim was shown by the work of Miser[3] in 1913. Miser determined the age of the

[1] Received January 28, 1935. Published by permission of the State Geologist of Tennessee and the Board of Graduate Studies of Washington University.

[2] SMITH, E. A. and JOHNSON, L. C. *Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama rivers.* U.S. Geol. Survey Bull. 43: 95. 1887.

[3] MISER, H. D. in DRAKE, N. F. *Economic geology of the Waynesboro quadrangle (Tennessee).* Tenn. Geol. Survey, Resources 4: 107. 1914.

gravels exposed in the Waynesboro quadrangle by tracing the overlying red sands (Eutaw formation) into Hardin County where he found a locality showing Cretaceous fossils.

STRATIGRAPHIC RELATIONS

Deposits of Upper Cretaceous age in Tennessee outcrop in a roughly wedge-shaped area which crosses the State in an approximate north-south direction, the greatest areal distribution of the Upper Cretaceous being west of the Tennessee River. This area is about 70 miles wide along the southern boundary of the State, but narrows until at the Kentucky line it is only about 15 miles in width. In the southern counties bordering the Tennessee River the following stratigraphic and lithologic units of the Upper Cretaceous have been recognized:

Ripley formation — Owl Creek tongue; McNairy sand member; Coon Creek tongue

Selma clay

Eutaw formation — Coffee sand member; Tombigbee sand member

Tuscaloosa formation

The Tuscaloosa formation on the western Highland Rim rests unconformably upon Mississippian limestones of Warsaw and St. Louis ages. In the southern counties the Tuscaloosa is overlain by the red micaceous Eutaw sand. In north-central Tennessee the Eutaw is definitely known only as small remnants in Stewart County along the divide between the Tennessee and Cumberland rivers.

LITHOLOGY

The Tuscaloosa formation in Tennessee is represented by well-rounded gravels, consisting essentially of chert with some limestone pebbles. Quartzitic pebbles are not uncommon. In the southwestern corner of the Waynesboro quadrangle Miser[4] noted that the top 30 feet of the Tuscaloosa consisted of "loose gravel, mostly sandstone, quartzite, and quartz in red sand. Quartz pebbles are in greatest abundance." Jewell[5] observed pebbles of quartzite and glassy vein

[4] MISER, H. D. Communication. December, 1934.
[5] JEWELL, W. B. *Geology and mineral resources of Hardin County, Tennessee.* Tenn. Div. of Geol. Bull. 37: 45. 1931.

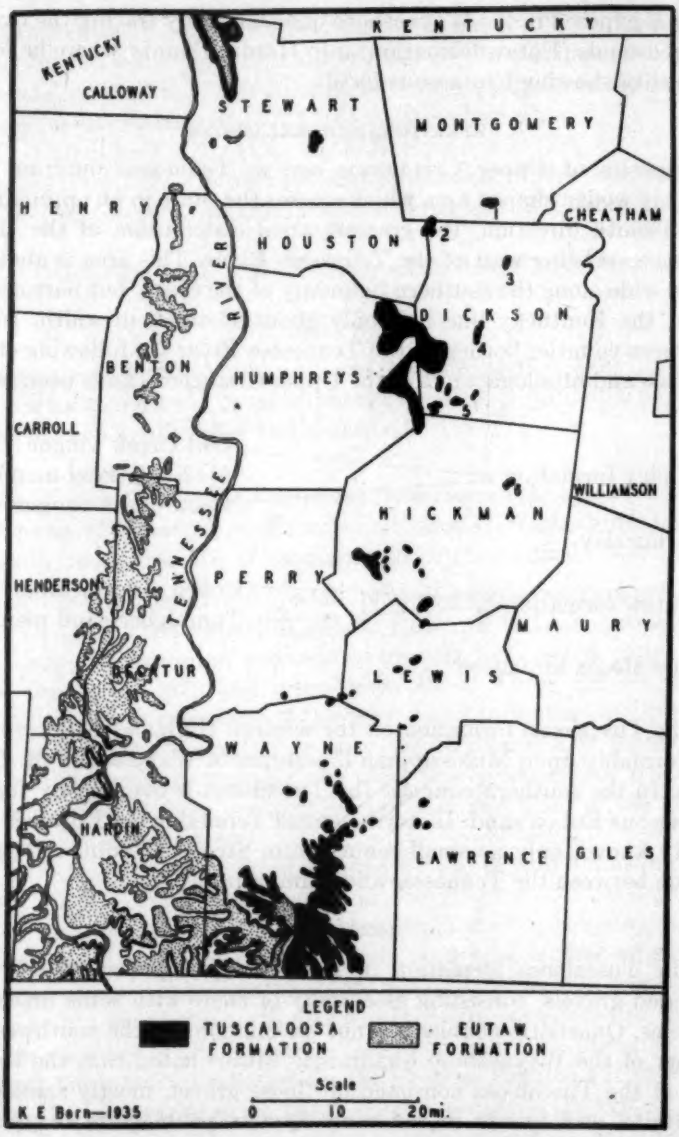


Fig. 1.—Sketch map showing exposures of the Tuscaloosa formation on the western Highland Rim of Tennessee. The numbers indicate new exposures and refer to descriptions in the text. The size of some of the smaller outliers has been exaggerated.

quartz in southeastern Hardin County. These pebbles have apparently had a distinct origin, but their source is speculative. The writer has noted quartzitic pebbles in exposures of the Tuscaloosa gravel on the northern part of the Rim, but always in rather small amounts.

All of the pebbles show definite evidence of water-wear, some of them closely approximating a sphere in shape. A few are polished. The average diameter is between one and two inches, although diameters of 6 to 12 inches have been observed. The color of the pebbles ranges from almost white to a very dark gray, the majority of them being light gray in color.

Locally, the gravels are intimately associated with sands and clays which generally occur as small lenses and pockets. The amount of sand and clay present decreases to the north. For the most part the constituents are poorly sorted although Jewell[6] observed that the lower portion of the Tuscaloosa in Hardin County was coarser than the top.

The matrix of the gravels consists of finely divided calcareous and siliceous material, much of which is clay. In certain localities, especially in the southern counties of the Rim, hydrous iron oxides have cemented the pebbles into a highly indurated conglomerate.

DISTRIBUTION OF THE TUSCALOOSA FORMATION

Miser[7] found that the Tuscaloosa gravels in the Waynesboro quadrangle were 150 feet thick and covered extensive tracts in the southwestern part of that area. In 1914 Wade[8] mapped the Tuscaloosa formation in Tennessee as far north as Perry and northern Lewis counties. Later he[9] traced remnants of the Tuscaloosa as far north as Trigg County, Kentucky. In 1920 Wade[10] gave a summary of his Upper Cretaceous studies in Tennessee in which the distribution and lithology of the Tuscaloosa formation were discussed. More recently Roberts[11] has described the Tuscaloosa and Eutaw formations of western Kentucky.

Formerly, the Tuscaloosa formation was considered to have a very

[6] JEWELL, W. B. Op. cit., p. 45.
[7] MISER, H. D. *Mineral resources of the Waynesboro quadrangle.* Tenn. Geol. Survey Bull. 26: 25. 1921.
[8] WADE, BRUCE. *Geology of Perry County and vicinity.* Tenn. Geol. Survey, Resources 4: 173. 1914.
[9] WADE, BRUCE. *The occurrence of the Tuscaloosa formation as far north as Kentucky.* Johns Hopkins Univ. Circ. 3: 102–106. 1917.
[10] WADE, BRUCE. *Recent studies of the Upper Cretaceous of Tennessee.* Tenn. Geol. Survey Bull. 23: 51–64. 1920.
[11] ROBERTS, J. K. *The Tuscaloosa formation in Kentucky.* Amer. Jour. Sci. 14: 465–472. 1927; *Cretaceous deposits of Trigg, Lyon, and Livingston counties, Kentucky.* Kentucky Geol. Survey 31: 281–326. 1929.

limited areal distribution east of the Tennessee River. However, more detailed studies have revealed isolated exposures of the Upper Cretaceous gravel some 30 to 40 miles east of the river. (See Fig. 1.)

An important link in this chain of outlying areas of gravels of Upper Cretaceous age is the gravels and sands in the vicinity of McEwen and Tennessee City on the central part of the western Highland Rim.

Fig. 2.—Exposure of the Tuscaloosa gravels in a new road cut, about 1½ miles east of Tennessee City. Width of the exposure is about 36 inches.

In this region the Tuscaloosa gravels cover several square miles and have a thickness of more than 25 feet. The gravels are well exposed in most of the new highway cuts between Dickson and McEwen. (See Fig. 2.) Just east of McEwen some 30 feet of the gravels are exposed which are underlain by the highly weathered St. Louis limestone and chert.

In 1930, while working on the brown iron ores of the western High-

land Rim, the writer[12] noted the Tuscaloosa gravels capping the higher hills near Louise in southern Montgomery County (1).* This occurrence of the Upper Cretaceous is some 10 miles farther east than any previously recognized in Tennessee.

During the summer of 1933 several more unmapped outliers of the Tuscaloosa gravels were found in Dickson County. In the extreme northwestern corner of the county, about 4½ miles northwest of Slayden, a small area of Cretaceous gravels occur at an altitude of 650–700 feet. This outlier is more or less continuous into southern Montgomery and eastern Houston counties (2).

About three-fourths of a mile south of Cumberland Furnace, in northern Dickson County, some 25 feet of the Tuscaloosa have been exposed by stream erosion near the crest of a ridge (3). In this exposure the gravels are especially well-rounded, light in color, and have been firmly embedded in sand and clay.

At various places along the north-south ridge bordering the road between Pond and the small village of Hortense, Tuscaloosa gravels were observed (4). Since no bed-rock is exposed in this immediate locality, the thickness of the gravels could not be determined.

South and east of the rather extensive outlier of the Tuscaloosa in western Dickson and eastern Humphreys counties, several small remnants of the Upper Cretaceous gravels were noted forming a veneer on some of the higher hills of the interstream area between Garner Creek and Piney River (5). In these localities, the finer sand and clay have been removed leaving the pebbles scattered as a mantle over the upland and embedded in the residual clays.

During the field season of 1934 a small exposure of gravels, very typical of the Tuscaloosa, was observed just north of the old Johnston iron ore pits, about 4 miles south of Wrigley Furnace in Hickman County (6). This is within 15 miles of the Central or Nashville Basin and is the most easterly occurrence of the formation yet discovered.

ORIGIN OF THE TUSCALOOSA FORMATION

The gravels of the Tuscaloosa formation on the western Highland Rim of Tennessee have been derived from Mississippian limestones and cherts. Mississippian fossils are commonly found in the pebbles. The coral, *Lithostrotion canadense*, indicative of the St. Louis limestone, has been observed towards the center of several pebbles.

[12] BORN, K. E. *The brown iron ores of the western Highland Rim of Tennessee.* Jour. Tenn. Acad. Sci. 7: 22. 1932.

* The numbers in parentheses refer to numbers of localities on the map, Fig. 1.

Berry,[13] basing his conclusions on certain resemblances to present deltas, believes that the Tuscaloosa formation in Alabama represents a series of Cretaceous deltas. This interpretation may be correct for Alabama, where the amount of sand and clay is greater and where paleobotanical evidence is present, but in Tennessee, and especially the northern part of the Highland Rim region, the clays and sands become much less abundant and the Tuscaloosa consists of gravel with only subordinate amounts of sand and clay. Roberts[14] noted this same constitution of the Tuscaloosa in Kentucky and he suggested a marine origin of the gravels. Field observations by the writer point toward a similar origin for the Tuscaloosa formation on the western Highland Rim of Tennessee. The Tuscaloosa gravels in this region are believed to be shore gravels deposited through overlap by the advancing Upper Cretaceous sea.

During the late Carboniferous and early and middle Mesozoic time the western Highland Rim is believed to have been a land mass. During this long geologic interval the land suffered erosion and Wade[15] suggested that the general area was a low-lying land. Wells[16] believes the region was reduced to a peneplain. In western Kentucky Sutton[17] has pictured the topography at the beginning of Tuscaloosa time as an irregular land surface in a mature stage of development. In the southwestern part of the western Highland Rim, Miser[18] interpreted the pre-Tuscaloosa topography as an uneven surface on which sink holes and underground channels were common.

As the result of downwarping, the Upper Cretaceous was initiated in the Embayment region by a transgressing sea which rounded the Mississippian limestones and cherts. The eastern limit of the Tuscaloosa sea in Tennessee is not definitely known, but the present recognized distribution of these basal gravels indicates that the sea encroached far upon the western flank of the Nashville arch.

The size and degree of rounding displayed by many of the pebbles appear to warrant a marine rather than a deltaic origin for the Tusca-

[13] BERRY, E. W. *The delta character of the Tuscaloosa formation.* Johns Hopkins Univ. Circ. **3**: 18–24. 1917; *Upper Cretaceous floras of the eastern Gulf region in Tennessee, Mississippi, Alabama, and Georgia.* U.S. Geol. Survey Prof. Paper **112**: 26–30. 1919.

[14] ROBERTS, J. K. *The Tuscaloosa formation in Kentucky.* Amer. Jour. Sci. **14**: 470–472. 1927.

[15] WADE, BRUCE. *Geology of Perry County and vicinity.* Tenn. Geol. Survey, Resources **4**: 176. 1914.

[16] WELLS, F. G. *Ground water resources of western Tennessee.* U.S. Geol. Survey Water-Supply Paper **656**: 22–23. 1933.

[17] SUTTON, A. H. *A pre-Cretaceous soil horizon in western Kentucky.* Amer. Jour. Sci. **22**: 450–451. 1931.

[18] MISER, H. D. *Mineral resources of the Waynesboro quadrangle.* Tenn. Geol. Survey Bull. **26**: 58–59. 1921.

loosa gravels on the western Highland Rim. Although our present knowledge of the Upper Cretaceous geography of this area is meager, it is believed, as suggested above, that the western Highland Rim was then a region of little or moderate relief. Considerable relief must be assumed to account for cobbles, many of which are 5 and 8 inches in diameter, to be washed into deltas. At present we have no basis for the assumption of any great amount of relief during the early Upper Cretaceous in west-middle Tennessee. No large pebbles are known in the present day stream gravels and it is probable that the present relief of the Rim region is greater than that of Cretaceous time. It appears, therefore, more likely that this rounding of Mississippian limestones and cherts has resulted from wave and tidal action of a sea transgressing a deeply weathered land area.

The width of the Tuscaloosa belt in Tennessee is also suggestive of a marine origin for the gravels. Very extensive deltas would be necessary to account for the rather wide distribution of the Tuscaloosa as indicated by the chain of outliers already known, and further detailed study of additional areas on the western Rim will probably reveal other outliers of the Tuscaloosa formation.

In the southern counties of the Rim and in the area west of the Tennessee River, the Tuscaloosa is overlain conformably by the Eutaw sand whose origin is certainly marine. In Hardin County, Jewell[19] has noted sands, similar to those in the Tuscaloosa, intercalated with the gravels and finer sands of the Eutaw formation. Continuous deposition is strongly suggested.

The presence of the Eutaw in Stewart County and in western Kentucky strongly suggests that these sands were deposited by the Upper Cretaceous sea when depth became favorable for the deposition of finer sediments. It is probable that the Selma and Ripley, and perhaps even younger formations, were laid down over a portion of the western Highland Rim.

Since the Tuscaloosa gravels form a basal conglomerate of a transgressing sea, the formation becomes progressively younger from south to north. The gravels in Dickson and Stewart counties are undoubtedly younger than any part of the gravels in northwestern Alabama and northeastern Mississippi. The Eutaw outliers in Stewart County and western Kentucky may be as young as basal Ripley.

The withdrawal of the Cretaceous sea from the Embayment area again subjected the Highland Rim to erosion and during the peneplanation of the late Cretaceous and early Tertiary most of the de-

[19] JEWELL, W. B. Personal communication. August, 1934.

posits of Upper Cretaceous age were removed. The existing patches of the Tuscaloosa and Eutaw in this region represent remnants of these formations which were probably continuous at one time over most or all of the present western Highland Rim.

BOTANY.—*A new species of* Dracaena *from the Department of Petén, Guatemala.*[1] C. L. LUNDELL, University of Michigan. (Communicated by H. H. BARTLETT.)

While collecting in the savanna country of the Department of Petén, Guatemala, in 1933, I discovered a grove of very interesting monocotyledonous trees in Monte Hiltun, a strip of forest separating Sabana Hiltun and Sabana Zotz. The trees were not in flower or fruit so that only sterile material was obtained. The species is apparently referable to the genus *Dracaena*.

Dracaena petenensis, sp. nov.

Arbor solida 6 usque ad 12 m. alta. Caulis 20–30 cm., basi expansa 70–90 cm., diam. Cortex tenuis fissuris irregularibus aliquantulum angustatisque et fastigiis paucis, inaequalibus, acutis, humilibus, griseus fusco-maculatus sub folia circulis griseis, fuscis vel rubris irregulariter circumdatus. Rami pauci, crassi, 15 cm. sub apice 10–15 mm. diam. Folia ramorum apice congesta, pendula, minutissime, serrulata glabri, griseo-viridia, 115–140 cm. longa, 18–20 mm. lata, basta dilata, amplexicaulia, integra scariosa, laminis linearibus, supra basin angustatis apice in aciem late setiformem coarctatis.

Type in the herbarium of the University of Michigan, *C. L. Lundell 3271*, collected in Monte Hiltun, Department of Petén, Guatemala, May 17, 1933. Cotype deposited in the United States National Herbarium, Washington, D. C.

The characters which distinguish *Dracaena petenensis* are (1) the massive trunk with expanded base, (2) the few, thick branches, and (3) the crowded, pendent, minutely serrulate, linear leaves 115 to 140 cm. long and 18 to 20 mm. wide. The other New World representative of the genus, *Dracaena americana* Donn. Smith, is occasionally encountered in the same region. It is a smaller tree with entire leaves 20 to 30 cm. in length.

[1] Received February 7, 1935. Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 527.

ZOOLOGY.—*The histology of nemic esophagi.* IV. *The esophagus of* Metastrongylus elongatus.[1] B. G. CHITWOOD, Bureau of Animal Industry and M. B. CHITWOOD.

This is the fourth paper of a series[2] dealing with the structure of the

[1] Received November 18, 1934.
[2] CHITWOOD, B. G., and CHITWOOD, M. B. *The histology of nemic esophagi.* I.

esophagi in various groups of nematodes. In this paper, insofar as possible, the same nomenclature for the various nuclei and cells will be used as in the previous papers.

GROSS MORPHOLOGY

The esophagus of *Metastrongylus elongatus* is clavate and may show grossly 3 indistinct regions, an anterior moderately narrow part or corpus, a very slightly narrower part, or isthmus, and a posterior wide part or bulbar region. The length of the esophagi in specimens studied varies from 262μ to 616μ; however, in the description a single specimen with an esophagus 450μ long has been used, since relative positions and lengths are fairly constant. In this specimen the corpus is approximately 162μ long, the isthmus 90μ long, and the bulbar region 198μ long. The dorsal esophageal gland opens into the lumen at the anterior end of the esophagus, while the subventral glands open into the lumen 126μ from the anterior end or 36μ from the posterior end of the corpus. The lumen is triradiate throughout the length of the esophagus; in the anterior part of the corpus the ends of the radii are very slightly rounded (Fig. 1b) and the cuticle is thickened.

NUCLEAR DISTRIBUTION

The corpus may be subdivided into 2 regions, a precorpus and a postcorpus, on the basis of nuclear distribution, these regions approximating the parts of the corpus of *Rhabditis*.

Precorpus. In the anterior part of the corpus, 22 nuclei, comprising 6 radials (r_{1-6}) and 16 nerve cells (n_{1-16}) have been constantly observed. In addition to these there are 4 questionable bodies (s_{1-4}), possibly nuclei of nerve cells, and 1 nerve cell nucleus (n_{8x}) which sometimes appears to be distinct and sometimes identical with n_8. The radial nuclei (r_{1-6}) are arranged in a single group of 6, 1 nucleus on each side of each sector 9 to 18μ from the anterior end of the precorpus.

The nerve cell nucleus n_1 is situated slightly to the right of the mediodorsal position, 7μ from the anterior end of the precorpus; n_{2-3} are situated near the center of the subventral sectors at the same level as n_1; n_{4-6} are situated about 15μ from the anterior end, near the center of each sector; n_7 is about 9μ from the anterior end of the precorpus and in the center of the dorsal sector, while n_{8-9} are near the same level as n_7, 1 nucleus in the center of each subventral sector; n_{10} is immediately posterior to n_9, while n_{8x} is immediately posterior to n_8 or possibly identical with n_8; n_{11-13} are approximately 38μ from the anterior end of the precorpus, 1 nucleus near

The esophagus of Rhabdias eustreptos (*MacCallum*, 1921). Zeit. f. Zellf. u. Micro. Anat. **22**: 29–37. 1934.

Ibid. II. *The esophagus of* Heterakis gallinae. Zeit. f. Zellf. u. Micro. Anat. **22**: 38–46. 1934.

Ibid. III. *The esophagus of* Oesophogostomum dentatum. This JOURNAL **24**: 557–562. 1934.

the center of each sector; and, finally, n_{14-16} are about 45μ from the anterior end.

The bodies s_{1-4} are near the external surface of the esophagus, s_{1-2} being about 18μ from the anterior end of the precorpus, 1 nucleus near the center of each subventral sector, while s_{3-4} are about 26μ from the anterior end of the precorpus and arranged similar to s_{1-2}.

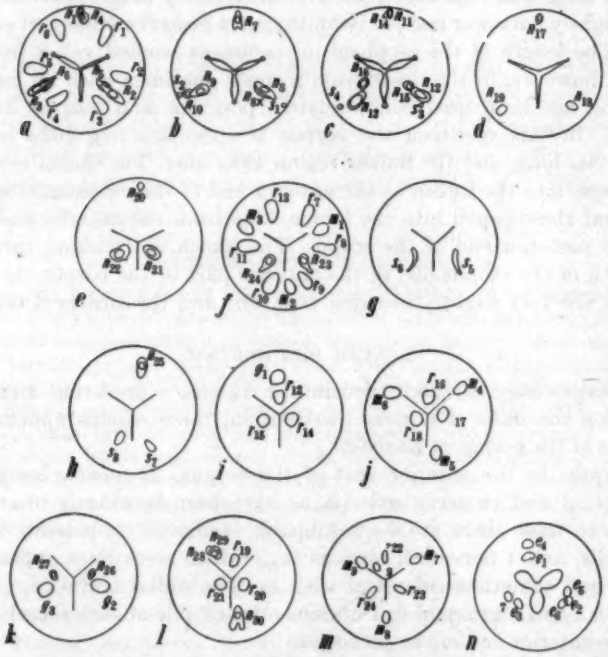


Fig. 1.—Nuclei of esophagus, diagrammatic representation. *r*, *m*, *s*, *g*, *n*, various types of nuclei; *a–c*, nuclei of precorpus; *d–h*, nuclei of postcorpus; *i–j*, nuclei of prevalvar region; *k–m*, nuclei of postvalvar region; *n*, nuclei of esophago-intestinal valve.

Postcorpus. The postcorpus contains 22 nuclei comprising 6 radial nuclei (r_{7-12}), 3 marginal nuclei (m_{1-3}), 9 nerve cell nuclei (n_{17-25}), and 4 nuclei (s_{3-6}), possibly those of nerve cells. The marginal nuclei (m_{1-3}) are arranged as a group of 3, 1 nucleus at the end of each esophageal radius, about 72 to 80μ from the anterior end of the esophagus or about 18 to 26μ from the anterior end of the postcorpus. The radial nuclei (r_{7-12}) are arranged similar to the radials (r_{1-6}) of the precorpus and are about 6 to 12μ posterior to the marginal nuclei.

The nerve cell nuclei consist of 2 groups of 3 nuclei (n_{17-19} and $_{20-22}$), 1 nucleus near the center of each sector, the first group situated approxi-

mately at the anterior end of the postcorpus, and the second group about 6 to 10μ posterior to the first group; a pair of subventral nerve cell nuclei (n_{22-24}) situated about 18 to 25μ from the anterior end of the postcorpus; and a single dorsal nerve cell nucleus (n_{25}) posterior to the orifices of the subventral glands, about 134μ from the anterior end of the corpus or 28μ from the posterior end of the corpus.

In addition to the above, there are 4 nuclei (s_{5-8}) which appear similar to those of nerve cells, but no cell body was observed. The first pair (s_{5-6}) is situated 6 to 10μ posterior to the radials r_{7-12}, 1 nucleus in each subventral sector, while the second pair (r_{7-8}) is near the posterior end of the postcorpus, about 6μ posterior to the last dorsal nerve cell (n_{25}).

Isthmus. As indicated by the distribution of nuclei, the isthmus is a region 90μ long between the corpus and the anterior part of the bulbar region, and contains no nuclei.

Prevalvar region. The anterior part of the bulbar region, the prevalvar region, contains 10 nuclei comprising 6 radial nuclei (r_{12-15}), 3 marginal nuclei (m_{4-6}), and 1 gland cell nucleus (g_1). The radial nuclei are arranged in 2 groups of 3 nuclei each, 1 nucleus of each group near the center of each sector; the first group (r_{12-15}) is about 6 to 12μ from the anterior end of the prevalvar region, while the second group (r_{16-18}) is situated 138 to 150μ from the anterior end of the region. The marginal nuclei (m_{4-6}) are arranged like those of the first group (m_{1-3}), and are situated at about the same level as the second group of radials (r_{16-18}) of this region.

The dorsal esophageal gland nucleus (g_1) is about half way between the 2 radial groups (r_{12-15} and $_{16-18}$) of this region. However, g_1 is quite variable in position, and in other specimens it may be situated further posterior, even at the level of the subventral gland nuclei.

Postvalvar region. The postvalvar region of the esophagus usually contains 16 nuclei as follows: 6 radials (r_{19-24}), 3 marginals (m_{7-9}), 2 gland cell nuclei (g_{2-3}), and 5 nerve cell nuclei (n_{26-30}). In addition to these, 1 more nucleus (s_9), possibly that of a nerve cell, has sometimes been observed. The radial nuclei are arranged in 2 groups of 3 nuclei each, 1 nucleus near the center of each sector; the first group (r_{19-21}) is situated 18 to 24μ from the anterior end of the postvalvar region, while the second group (r_{22-24}) is situated at the posterior end of the esophagus. The marginal nuclei (m_{7-9}) are arranged like the other margins (m_{1-3} and $_{4-6}$), and situated 6 to 10μ from the posterior end of the esophagus.

The subventral esophageal gland nuclei (g_{2-3}) are in the center of their respective sectors, at the anterior end of the postvalvar region in the particular specimen described here. Sometimes, however, these nuclei are situated in the prevalvar region, 6 to 10μ anterior to the last group of radials of that region (r_{16-18}).

The subventral nerve cell nuclei (n_{26-27}) are symmetrically placed, 1 nucleus near the center of each subventral sector, situated at approximately

the anterior end of the postvalvar region; the dorsal nerve cell nuclei (n_{28-29}) are situated just anterior to m_9, with 1 nucleus (n_{28}) anterior to the other (n_{29}); the ventral nerve cell nucleus (n_{30}) is a little to the left of the ventral esophageal radius, 6 to 12μ anterior to m_8. In addition to these nuclei, a right subdorsal nucleus (s_9) was observed in 1 series of sections; it appeared similar to the nucleus of a nerve cell but no cell body was observed.

Esophago-intestinal valve.—The esophago-intestinal valve consists of 2 parts, an anterior part with a trilobed lumen the wall of which contains 3 nuclei, 1 nucleus near the center of each lobe, and a posterior part with a rounded lumen the wall of which contains 4 nuclei, of which 1 nucleus is dorsal, 2 left subventral, and 1 right subventral.

CHARACTER OF NUCLEI

The radial nuclei each contain a moderate sized nucleolus lying in a finely granular, very delicately basophilic nucleoplasm. In cross section the radial nuclei of the corpus (r_{1-12}) are elongated, 7.9μ long by 3.7 to 4μ wide, their long axes corresponding to the radius of the esophagus; those of the prevalvar region (r_{13-18}) are subtriangular, 6.2 to 7μ long by 5 to 5.8μ wide, while those of the postvalvar region (r_{19-34}) are ellipsoidal, 6.2 to 7μ long by 2.9 to 3.3μ wide.

The marginal nuclei are similar to the radial nuclei except that the nucleolus is slightly larger in proportion to the nucleus, and sometimes a second, smaller nucleolus is present. All of the marginal nuclei are ellipsoidal to slightly subtriangular. The nuclei of the first group (m_{1-3}) are about 3.4μ long by 3.3μ wide, those of the second group (m_{4-6}), 7.9μ long by 5μ wide, and those of the third group (m_{7-9}), 4.5μ long by 2.5μ wide.

The gland cell nuclei are the largest nuclei of the esophagus, the dorsal (g_1) 6.2μ long by 6.2μ wide, and the subventrals (g_{2-3}) 7μ long by 8.7μ wide. Each of these nuclei contains a proportionally large nucleolus in a very homogenous, basophilic nucleoplasm.

The nerve cells consist of several types, the nuclei varying greatly in size and character. A brief description of these nuclei may be clarified through reference to figure 4. The dorsal nerve cell nuclei of the corpus are of 3 types, as follows: n_1 is of a type containing a nucleolus in a nucleoplasm which shows no affinity for stain; $n_{4,7,17,}$ and $_{25}$ are of a type containing a bilobed, irregular nucleolus, or 2 nucleoli in a nucleoplasm basophilic at the margin; $n_{11,14,}$ and $_{20}$ are of a type containing a deeply basophilic nucleoplasm without distinct nucleolus. Of these, n_{25} appears to be a cell of the commissure at the base of the postcorpus, the cell body being large and the cytoplasm homogenous and eosinophilic; n_4 and $_7$ have similar cytoplasm or cell bodies, but are apparently bipolar; the remaining cells have a very small cell body and are spindle shaped and bipolar.

The subventral nerve cells of the corpus contain 2 types of nuclei, $n_{2-3,5-6,15-16,22-24}$ having a nucleoplasm basophilic at the margin, while $n_{8-9,10,12-13,}$

$r_{18-19,21-22}$ contain a few basophilic granules but the nucleoplasm is not basophilic at the margin. All of the subventral nerve cell nuclei contain a bilobed nucleus or 2 separate nucleoli; the cells appear to be bipolar and the

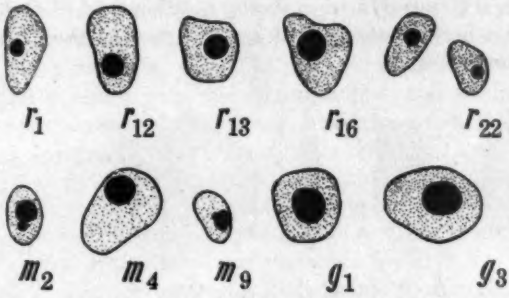


Fig. 2.—Individual nuclei of esophagus. Labelled as in fig. 1.

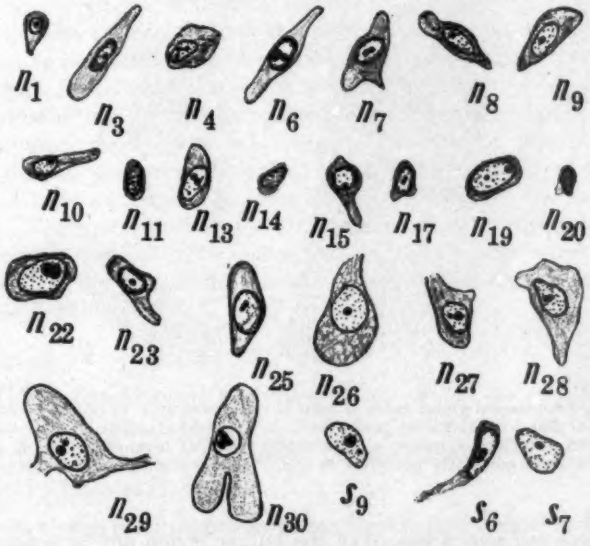


Fig. 3.—Nerve cells of esophagus. Labelled as in fig. 1.

cell bodies homogenous and basophilic, but the size and shape varies with the individuals cell (Fig. 4).

The bodies of the corpus labelled *s* are not all of the same character. Those labelled s_{1-4}, possibly nerve cells, are strongly basophilic and somewhat similar to n_{11}, but no cell bodies were observed (the writers are not entirely

certain that they are nuclei); s_{5-6} are obvious nuclei with lobed nucleoli and clear nucleoplasm, 1 body lying near the inner ventral side of the anterior part of each subventral gland and surrounded by deeply staining cytoplasm, but no cell wall observed; s_{7-8} are similar nuclei situated ventral and medial to the subventral glands. Nuclei in similar positions and of similar character are present in other nematodes, but a comparison of these nuclei will not be taken up until later.

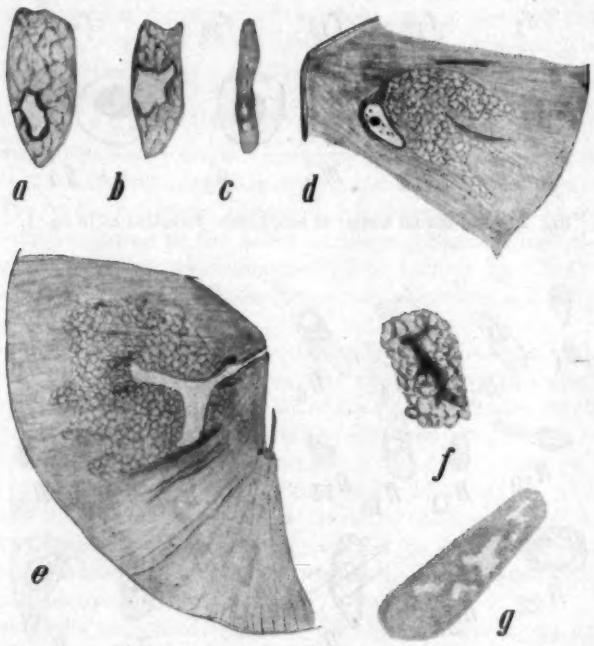


Fig. 4.—Esophageal gland mass as seen in cross section. *a*, dorsal gland near orifice; *b*, dorsal gland immediately posterior to *a*; *c*, dorsal gland at level of m_{1-1}; *d*, subventral gland anterior to orifice; *e*, subventral gland at level of orifice; *f*, subventral gland in section immediately posterior to *e*; *g*, subventral gland in anterior part of bulbar region.

The nerve cell nuclei (n_{26-30}) of the bulbar region are, in general, larger nuclei than those of the corpus (Fig. 3); all contain a lobed nucleolus in a clear nucleoplasm having a few basophilic granules. The cell bodies are large, the cytoplasm lightly eosinophilic and sometimes vesicular (see n_{30} of Fig. 4). All of these cells appear to be commissural cells; they have 2 chief processes which come off at the same side of the cell body and then diverge. The single *s* nucleus (s_9) of the bulbar region appears to be similar to the nuclei of the nerve cells of the same region but no cell body has been observed.

ESOPHAGEAL GLANDS

The dorsal esophageal gland has a very short narrow duct lined with cuticle which is continuous with a protoplasmic central tubule having a thick deeply basophilic wall. This tubule becomes wider and bifurcates posterior to the orifice of the gland, each branch giving off numerous short branches which are continuous with the coarsely reticulate, deeply basophilic cytoplasm of the gland (Fig. 4a–b). In the anterior part of the precorpus the dorsal gland is rather wide and circumscribed, and occupies a central position in the dorsal sector. In the remainder of the corpus the dorsal gland is narrow (Fig. 4c) and the gland mass finely reticular to alveolate; it becomes a narrow strand in the region of the isthmus, and again larger in the anterior part of the bulbar region. Near the level of its nucleus, the dorsal gland becomes multilobed and occupies a large part of the dorsal sector; in this region the cytoplasm is dense and contains a few alveoli.

The subventral glands extend some distance anterior to their orifices; in this region the cytoplasm is very finely reticulate (Fig. 4d). Near the level of their orifices the subventral glands become multilobed but the finely reticular structure remains. Each gland has an extremely short duct lined with cuticle, and continuous with this duct is a thick-walled protoplasmic tube which is immediately multibranched, the branches continuous with the reticulum. Posterior to this region the gland mass, like the dorsal gland, becomes smaller until it is finally reduced to a delicate strand of protoplasm in the isthmian region. The subventral glands become enlarged in the posterior part of the prevalvar region, become lobed in the region of their nuclei, and then continue to be large and lobed nearly to the base of the esophagus. The protoplasm is dense throughout this region except in the part adjacent to the lumen. In general, the mass of the subventral glands is less basophilic than that of the dorsal, and sometimes appears to be very slightly eosinophilic.

ZOOLOGY.—*Development and morphology of the cestode,* Hymenolepis cantaniana, *in coleopteran and avian hosts.*[1] M. F. JONES and J. E. ALICATA, Bureau of Animal Industry. (Communicated by ELOISE B. CRAM).

Previous to the preliminary note by Alicata and Jones[2] in 1933, the life history of the poultry cestode, *Hymenolepis cantaniana,* was unknown. There was reported at that time the finding, in the dung beetle *Ataenius cognatus,* of proliferating larvae which consisted of a mycelium-like structure, numerous buds, and partially or completely de-

[1] Received March 12, 1935.

[2] ALICATA, J. E., and JONES, M. F. *The dung beetle,* Ataenius cognatus, *as the intermediate host of* Hymenolepis cantaniana. Jour. Parasitol. 20: 244. 1933.

veloped cysticercoids (Fig. 1). The larvae developed to maturity in chicks and were identified as *H. cantaniana*. The present paper gives a more detailed account of the development and morphology of the proliferating larva of this cestode in the intermediate host, *Ataenius cognatus*. Since the previous report, 2 additional beetles, *Ataenius stercorator* from Puerto Rico and *Choeridium histeroides* of local origin have been found to harbor similar proliferating larvae, presumably those of *H. cantaniana*. The larvae from *Ataenius stercorator* were collected by Dr. H. L. Van Volkenberg and sent to the Zoological Division for identification, with the statement in a personal communication that this material was identical with that which he reported, but

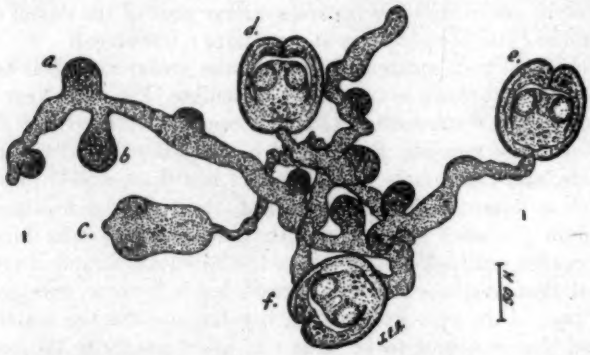


Fig. 1.—Larvae of *Hymenolepis cantaniana* from *Ataenius cognatus*. Natural infestation. *a*, *b*, *c*, developing cysticercoids; *d*, *e*, *f*, apparently mature cysticercoids still attached to branching larval tissue. After Alicata and Jones, 1933.

did not describe in 1931.[3] In the present paper, geographical distribution and seasonal occurrence of the intermediate hosts are discussed briefly. A short description of the adult worm, with data regarding its development, subsequent to laboratory feedings, in the chicken, guinea fowl, and bobwhite quail, also are included.

The authors wish to thank Dr. E. A. Chapin of the U. S. National Museum for identifying beetles and for supplying data regarding distribution of the 3 beetles reported as intermediate hosts.

SOURCE OF LARVAL MATERIAL

The greater part of the cestode larvae available for study occurred as natural infestations in numerous specimens of *Ataenius cognatus;* larvae were observed also in one specimen of *Choeridium histeroides*.

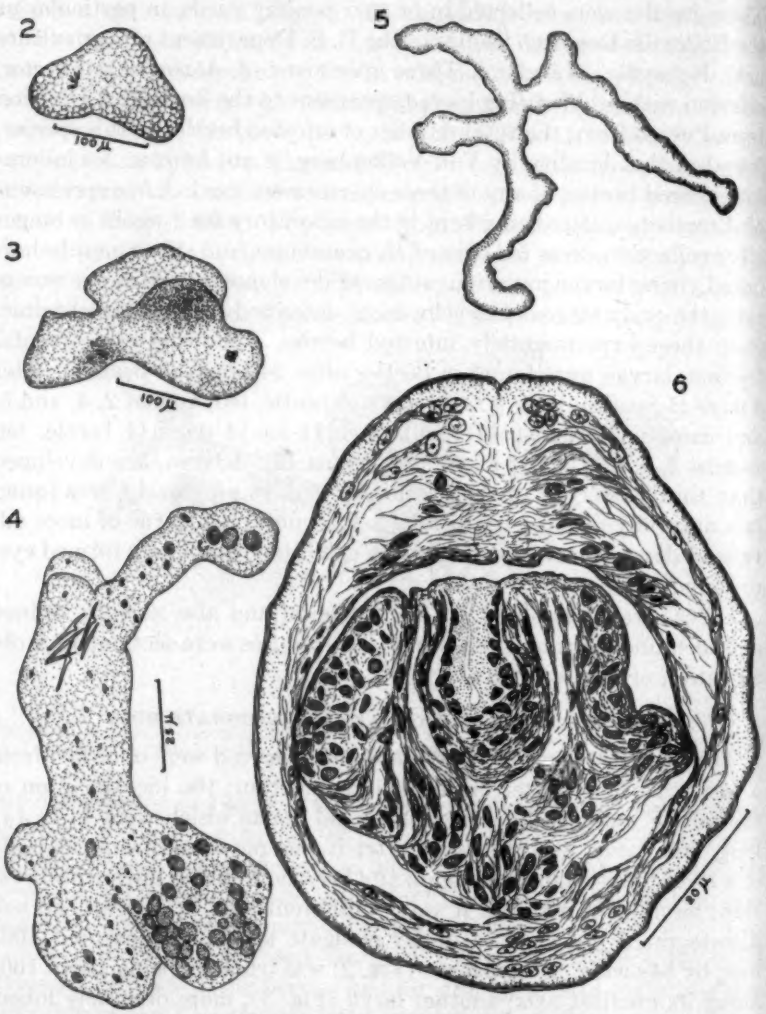
[3] VAN VOLKENBERG, H. L. *Report of parasitologist.* Report Puerto Rico Agric. Exp. Sta. 1930: 38–40. 1931.

These beetles were collected in or near poultry yards, in particular at the Beltsville Research Center of the U. S. Department of Agriculture near Beltsville, Maryland. Three specimens of *Ataenius stercorator*, infested with proliferating larvae, were sent to the Zoological Division from Puerto Rico; the total number of infested beetles of this species, found in that locality by Van Volkenberg, is not known. No laboratory-reared beetles of any of these species were used. A few specimens of *A. cognatus*, after being kept in the laboratory for 2 weeks or longer after collection, were fed eggs of *H. cantaniana* and subsequently harbored young larvae in various stages of development. With one exception, the early stages of development described below were obtained from these experimentally infected beetles. Following experimental feeding, larvae were found in beetles after 24 hours (2 beetles), after 8 days (1 beetle), after 9 to 12 days (1 beetle, fed August 2, 4, and 5, and examined August 14), and after 11 to 14 days (1 beetle, fed August 2, 4, and 5, and examined August 16). A larva, less developed than those observed in the beetles fed 8 days previously, was found in a naturally infested beetle which also contained larvae of more advanced development, some of which exhibited completely formed cysticercoids.

Larvae were examined as fresh material and also as both stained and unstained permanent mounts. Two beetles were sectioned for observation of larvae *in situ*.

DEVELOPMENT OF LARVA IN INTERMEDIATE HOST

The youngest larvae of *H. cantaniana* observed were obtained from a beetle 24 hours after experimental infection; the identification of the larvae was based on the embryonal hooks which were 13 to 14μ long. One larva, observed soon after it was recovered from the body of a beetle, was slightly elongate and became rounded during observation; as unfixed material it was undifferentiated in appearance and disintegrated quickly. A similar elongate specimen measured 106μ long by 54μ wide. A third larva (Fig. 2) was trilobed, being about 160μ along its greatest axis; another larva (Fig. 3), more definitely lobed, measured about 200μ along its greatest axis. At least 6 small lobes or branches were exhibited by a smaller larva (Fig. 4) of unknown age which measured about 140μ along its greatest axis after having been mounted and stained with methylene blue. It is considered typical of early branching or proliferating larvae of this species; its nuclei are comparatively large and are definitely more concentrated near the tip of each branch. Apparently the first few branches elongate (Fig. 5)



Figs. 2–6.—Larvae of *Hymenolepis cantaniana* from *Ataenius cognatus*. Figs. 2–3.—Obtained 24 hours after experimental feeding. Fig. 4.—Young larva, natural infestation. Fig. 5.—Sketch of branching larva, 8 days after experimental feeding. Fig. 6.—Completely formed cysticercoid. Sectioned material.

before many new buds arise. A larva recovered from a beetle fed 8 days previously had a maximum axis length of 605μ and exhibited considerable proliferation, there being 4 distinct elongate branches and 2 rounded buds. Larvae from a beetle fed 9 to 12 days previously con-

sisted of numerous branches and a few buds which represent partly developed cysticercoids. Larvae recovered from a beetle of the same lot fed 11 to 14 days previously consisted of numerous branches, buds, partly formed and completely formed cysticercoids, the latter representing the infective larvae proper.

To summarize briefly on the basis of observations on numerous larvae, the hexacanth embryo develops into lobes, then a branching, mycelium-like structure, the branches of which bear buds which may develop into new elongate branches or directly into cysticercoids. In general, on the branching larval stem, the development of a bud into a cysticercoid resembles the more commonly observed development of hexacanth embryo into cysticercoid of other species of tapeworms, except that the embryonal hooks of *H. cantaniana* remain in the basal stem, or are lost, and consequently are not involved in the development of bud into cysticercoid (Figs. 1, 7, 8). A larva early in its development, still somewhat globular except for the area of attachment to the stem, is about 35 to 50μ in diameter; the cell nuclei are closer together than are those of the proliferating stem itself. These globular structures, while remaining attached to the stem, elongate and become ovoid; with further elongation constrictions appear; the first constriction results in a larva made up of a smaller proximal region, nearer the stem, and a larger distal region (Fig. 1c). Such larvae, with one constriction, may be 70 to 85μ long by 35μ in diameter through the proximal region and about 40 to 45μ in diameter through the distal region. Cells of the distal region are the more concentrated; in the median and proximal regions the outer cells lie close together, but the inner cells have elongate projections and form a loose tissue which represents the "primitive cavity" of the developing cysticercoid. While the first constriction, mentioned above, is becoming more marked, there occurs cell differentiation in the distal region in 4 areas which represent the future suckers. At the distal tip, a few large cells are to be observed which later develop as a projection representing the future rostellum; at an early stage this projection is 10.5μ long by 7μ in diameter.

A second constriction appears proximal to the suckers, and differentiation progresses. The region of loose fibrous tissue becomes more marked, suckers become more distinct, and a narrow cavity appears in the projecting rostellum, the latter 22μ long by 8μ in diameter. An individual specimen at this stage of development is 112μ long, 102μ in diameter through the suckers, 42.5μ through the median region, and 52.5μ through the posterior region.

A cysticercoid apparently just beginning to invaginate is 120μ long. Suckers appear to be completely formed, or nearly so, but the rostellum is not completely developed. *H. cantaniana* evidently belongs to the group of cestodes in which scolex differentiation of the larva is partially but not entirely completed before invagination. Invagination itself occurs rapidly, to judge from the comparatively few larvae observed in the process.

The region of attachment to the main stem elongates as the bud develops into a cysticercoid; it is fragile and breaks or disintegrates easily during observation of fresh material.

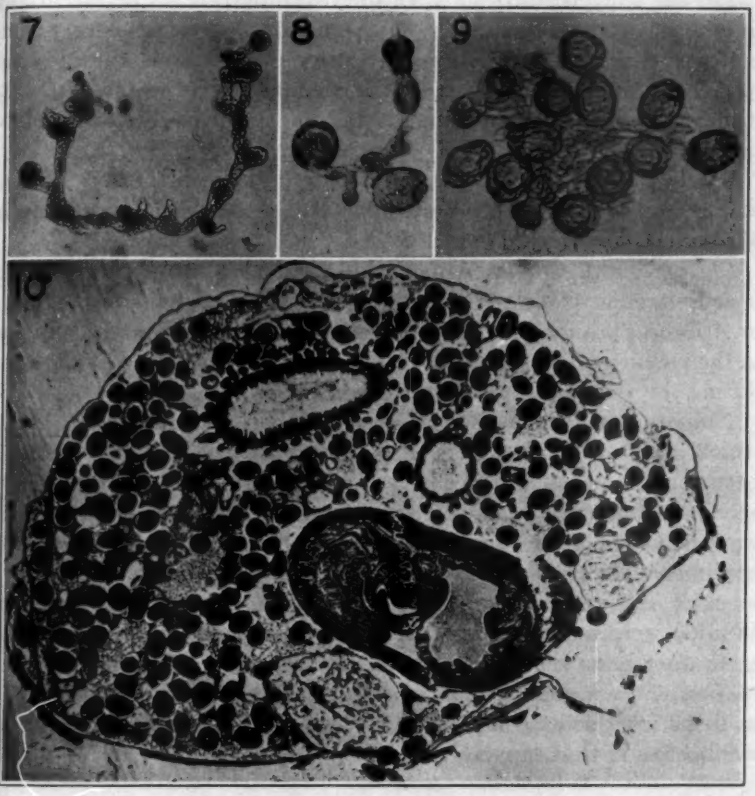
Calcareous corpuscles are first observed in young rounded forms; larvae with one constriction may contain 4 to 10 calcareous corpuscles which, as a rule, are median or distal in position. In completely formed cysticercoids as many as 40 have been counted; these are located in the inner cyst wall and thus are in the neck region of evaginated specimens.

Completely formed cysticercoids or infective larvae (Fig. 6) are spherical or ellipsoidal in shape or, in heavy infestations, may be irregularly compressed. They are comparatively small, 90μ by 68μ to 140μ by 102μ in diameter. The cyst wall consists of a thin cuticula, an inconspicuous basal membrane and sub-cuticular layer, a fibrous zone with irregular spaces representing the old "primitive cavity," and the inner cuticula. The scolex, lying in a small invagination cavity, is about 50 to 72μ in diameter; suckers are 20 to 26μ in diameter, the rostellum is about 22 to 24μ long, only the small rosteller cavity being easily observed in most material. No hooks could be seen on the scolex, although wrinkles of the cuticular lining of the rostellar cavity suggested minute hooks in certain specimens.

Completely formed cysticercoids may remain attached to the proliferating larval tissue by short stems or may lie free in the body cavity of freshly dissected beetles. Although cysticercoids become detached readily during the examination of the material, they do not evaginate readily in tap water, even when stimulated by tapping or heating the slide. Cysticercoids of *H. cantaniana* differ in this respect from those of *H. carioca* or *Raillietina cesticillus*, which evaginate much more readily.

On the basis of the limited material derived from experimental infections of beetles, it is concluded that at room temperature during mid-summer, in Washington, D. C., 11 to 14 days, as a minimum, are required for the cysticercoid to become completely formed. The time necessary for development at lower temperatures is not yet known.

Larval proliferation and development of cysticercoids appear to continue for at least 4 weeks, since in one lot of beetles, collected in mid-October and held so that re-infection was not possible, both completely formed and developmental stages were observed until early in December when the last beetle was killed. However, in some beetles,



Figs. 7–9.—Larvae of *Hymenolepis cantaniana* from *Ataenius cognatus*. Natural infestations. Fig. 10.—Section through specimen of *A. cognatus* containing numerous larvae of *H. cantaniana*. Natural infestation.

it has been noted that there were numerous completely formed cysticercoids (Fig. 9) along the branching structures, but only very few developing forms; this might be interpreted as indicating that there is a limit to the period of proliferation of the larva. Surprisingly large numbers of cysts may be found in a single beetle (Fig. 10). As reported previously, the number of cysticercoids counted in one beetle

was 1163, and in another individual, 2217; developing cysticercoids were not included in either count.

SEASONAL OCCURRENCE AND DISTRIBUTION OF INTERMEDIATE HOSTS

The dung beetle, *Ataenius cognatus* Leconte, has been collected near Beltsville, Maryland, from April to November, inclusive. According to information supplied by Dr. E. A. Chapin, this species is very common and widely distributed in the United States and is known to occur as far south as Mexico. In the vicinity of Washington, D. C., it may be collected at any time during the year when weather conditions are favorable.

Ataenius stercorator Fab. is believed to occur from Texas to Brazil and more generally in the West Indies. It has also been reported from Madeira.

Choeridium histeroides Weber has been collected in poultry yards near Beltsville, Maryland, but less frequently than *Ataenius cognatus* or *Aphodius granarius*. It is considered as being moderately common in the vicinity of Washington, D. C., and it may be found at any time during the year if the weather is favorable.

Numerous specimens of *Aphodius granarius* and *Onthophagus* spp., which also were collected from poultry yards near Beltsville, have been found consistently negative for larvae of *H. cantaniana*. Of 10 specimens each of *Aphodius granarius* and of *Ataenius cognatus* which were collected at the same time, from the same poultry yard, the specimens of *Aphodius granarius* were negative while 8 of the specimens of *Ataenius cognatus* contained larvae of *H. cantaniana*. Efforts to infect specimens of *Aphodius granarius* with *H. cantaniana* in the laboratory have been unsuccessful. On the basis of our present information, *Hymenolepis cantaniana* appears to exhibit more specificity as to its intermediate host than do other poultry tapeworms which use beetles in that capacity.

DEVELOPMENT OF HYMENOLEPIS CANTANIANA IN DEFINITIVE HOSTS

Birds were fed larvae from the beetle, *Ataenius cognatus*, as listed in table 1. No cestodes other than *H. cantaniana* were found in any bird and control birds remained free of cestodes.

As noted in table 1, one chick (a), which was examined 11 days after experimental feeding with *H. cantaniana* larvae, contained immature specimens of *H. cantaniana* about 3.5 mm. long. Chick G7068 passed eggs of *H. cantaniana* 14 days after experimental feeding; chick No. 91 passed eggs in droppings, and chick G7047 contained mature speci-

TABLE 1.—DEVELOPMENT OF HYMENOLEPIS CANTANIANA

HOST	DESIGNATION OF HOST	DATE OF FEEDING	DATE OF AUTOPSY	POST-MORTEM FINDINGS
Chick	1	Oct. 26, 1932	Nov. 2, 1932	Negative
	J3	Oct. 26, 1932	Nov. 14, 1932	About 10 almost mature tapeworms
	a	Oct. 28, 1932	Nov. 8, 1932	About 12 immature tapeworms
	b	Nov. 10, 1932	Dec. 2, 1932	Negative
	91	Nov. 15, 1932	Dec. 7, 1932	Tapeworms present (eggs in feces, Dec. 1)
	G7047	Nov. 16, 1932 (ca. 500 cysts)	Dec. 2, 1932	21 mature tapeworms
	G7068	Nov. 16, 1932 (ca. 230 cysts)	Dec. 20, 1932	44 mature tapeworms (eggs in feces, Nov. 30)
	365	June 19, 1933	Died July 3, 1933	? (Bird decomposed)
	305	July 8, 1933	Aug. 17, 1933	Few mature tapeworms
	310	July 8, 1933	Aug. 17, 1933	Few mature tapeworms
	316	July 8, 1933	Aug. 17, 1933	About 10 tapeworms
	345	July 21, 1933	Oct. 3, 1933	Tapeworms present
	324	Aug. 21, 1933	Sept. 21, 1933	Tapeworms present
	406	Sept. 20, 1933	Nov. 14, 1933	Numerous tapeworms
	407	Sept. 20, 1933	Jan. 4, 1934	Negative
	445	Sept. 20, 1933	Jan. 4, 1934	Negative
	421	Sept. 20, 1933	Mar. 10, 1934	Few tapeworms
Bobwhite quail	219	Aug. 27, 1934	Sept. 28, 1934	About 113 tapeworms
Guinea fowl	294	Aug. 27, 1934	Nov. 20, 1934	About 15 tapeworms

mens of *H. cantaniana*, 16 days after experimental feedings. Chick J3, examined 19 days after experimental feeding, contained specimens with egg-filled segments, but with the eggs apparently still unripe; no eggs or gravid segments were found in the posterior regions of the intestine. It is concluded that the time necessary for development of *H. cantaniana* in its definitive host probably varies from 2 to 3 weeks.

In all, 12 chickens, 1 guinea fowl and 1 bobwhite quail have become infested with *H. cantaniana* after being fed beetles containing proliferating cestode larvae. Four chicks remained negative after being fed and a fifth chick (365), which died, was so decomposed when examined that although no worms were found the negative results are somewhat inconclusive since, had specimens been present, they might well have been disintegrated by the time the bird was examined. It is interesting to note that one bird (421) remained infested from September 20, 1933, to March 10, 1934, a period of about 5½ months. Three birds were fed eggs of *H. cantaniana* in an attempt to demonstrate a direct life cycle, but all three birds remained negative for tapeworms.

MORPHOLOGY OF ADULT

Hymenolepis cantaniana (Polonio, 1860) Ransom, 1909. *Hymenolepis:* Worms up to 2.2 cm. long by 400μ wide. Scolex 120 to 160μ in diameter; suckers unarmed, 60 to 70μ in diameter; rostellum unarmed, 80 to 85μ long by 35μ wide, sac-like, the narrow cavity lined with cuticula sometimes wrinkled and striated in appearance. Genital pores unilateral, anterior to middle of segment margin. Testes 3, 1 aporal, 2 poral, usually arranged in a transverse row, but 1 aporal testis may be anterior and median, or dorsal and median, to other aporal testis; testes obscured rapidly by developing ovary and uterus, and at no time conspicuous in strobila. External seminal vesicle near median line; internal seminal vesicle nearly filling cirrus pouch. Cirrus pouch thin-walled, elongate, 70 to 95μ long, extending nearly to middle of mature, but not of gravid, segments. Vagina ventral to cirrus pouch, expanding into comparatively large oval seminal receptacle, for a time the most prominent structure in the segment. Ovary, when mature, sometimes extending to lateral excretory vessels and to anterior border of segment. Uterus sac-like, eventually filling nearly the whole segment and containing about 10 to 20 eggs. Eggs spherical, 45 to 60μ in diameter; oncosphere 22 to 25μ in diameter; embryonal hooks 13 to 14μ long.

Individual gravid segments or groups of 2 or 3 segments are found occasionally in droppings; however, as a rule, segments disintegrate early and individual eggs are found in the posterior portion of the intestine and in droppings. Embryonal activity has been observed in eggs still present in gravid segments of freshly collected strobilae, in eggs from fresh droppings, and also in eggs kept as long as 6 days in a refrigerator (45° to 50°F.). Embryos are not easily activated on a slide as are those in gravid segments of *Davainea proglottina* and *Raillietina cesticillus*.

Hosts.—Definitive: Galliformes (*Gallus gallus, Meleagris gallopavo, Pavo cristatus, Phasianus colchicus, Colinus virginianus* and *Numida meleagris*).

Intermediate: Coleoptera (*Ataenius cognatus, A. stercorator,* and *Choeridium histeroides*).

Location.—Small intestine, usually duodenum of definitive host; body cavity, connective tissue and, less commonly, muscular tissue of intermediate host.

Geographical distribution.—Europe (France, Spain, Italy, Jugo-Slavia and U. S. S. R.), Asia (Japan and Indo-China), South America (Brazil), and North America (United States, including Puerto Rico).

SUMMARY

Early developmental stages of proliferating larvae were obtained from 5 specimens of the beetle, *Ataenius cognatus*, which were dissected at varying periods after having been fed eggs of *Hymenolepis cantaniana*.

The hexacanth embryo was found to develop into a larva of several lobes, the latter elongating to form a somewhat branched, mycelium-like, structure; buds arose along the branches which developed into new branches or directly into cysticercoids containing the unarmed scolex characteristic of the species. Development of the bud into the cysticercoid resembles in general the development of other *Hymenolepis* larvae; the process consists of elongation, slight cavity formation, constriction, differentiation of scolex in most details and in-

vagination of cephalic region, resulting in a rounded cysticercoid. Scolex differentiation of *H. cantaniana* is partially, but not entirely, completed before invagination.

On the basis of the experimental findings, the minimum time required for development of an infective larva in the beetle host is from 11 to 14 days; proliferation of the larva and development of new cysticercoids apparently may continue for at least 4 weeks.

Development of the adult worm in the chicken requires at least 14 days and the time probably varies from 2 to 3 weeks.

Twelve chickens, 1 quail and 1 guinea fowl became infested with *Hymenolepis cantaniana* as a result of feeding branched cestode larvae obtained from naturally infested specimens of the beetle, *Ataenius cognatus*.

The beetles *Choeridium histeroides* and *Ataenius stercorator* are reported as additional intermediate hosts, on the basis of their harboring larvae similar to those found in *Ataenius cognatus* and known to be larvae of *H. cantaniana*.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETY

BOTANICAL SOCIETY

SPECIAL MEETING

A special meeting was held in the auditorium of the Interior Department Building on December 11, President W. W. DIEHL presiding; attendance 80.

Program: F. A. MCCLURE: *A garden of oriental bamboos* (illustrated with lantern).

H. H. BARTLETT, University of Michigan. Professor Bartlett discussed the activities and recommendations of the subcommittee on the reorganization of the National Botanic Garden. He emphasized the fact that the present appropriation for the botanic garden was sufficient to maintain a garden of high professional standards, especially in view of the availability of cooperating agencies in Washington. Under the proposed plan the garden would be administered by a botanist of recognized standing, as Director, under the auspices of the Joint Congressional Committee on the Library. An advisory board of directors with representatives from the Smithsonian Institution, the Department of Agriculture, and various scientific societies would also be appointed.

Following Professor Bartlett's remarks, discussion of the proposed plan ensued, and the Society took formal action approving the reorganization of the National Botanic Garden along the general lines outlined in Professor Bartlett's report. The secretary was directed to notify the Chairman of the Joint Congressional Committee on the Library of the Society's action.

262ND MEETING

The 262nd regular meeting was held in the Assembly Hall of the Cosmos Club, January 8, 1935, President DIEHL presiding; attendance 95. J. E. MCMURTREY was elected to membership.

Notes and reviews: Brief reports on the Pittsburgh meeting of the American Association for the Advancement of Science were presented as follows: Mycology, J. A. STEVENSON; Phytopathology, H. P. BARSS; General Botany, A. S. HITCHCOCK; Plant Physiology, C. F. SWINGLE; Horticulture, G. M. DARROW; Publicity, FRANK THONE. A report of the Chicago meeting of the American Society of Bacteriologists was presented by N. R. SMITH.

Program: J. R. CHRISTIE: *The development of nematode root galls* (illustrated with lantern).—Abstract published in Phytopathology, December 1934. To be published in full in Phytopathology.

J. R. SWALLEN: *The arid regions of northeastern Brazil* (illustrated with lantern).

263RD MEETING

The 253rd regular meeting was held in the Assembly Hall of the Cosmos Club, February 5, 1935, President DIEHL presiding; attendance 80. HARRY A. ALLARD and HENRY E. ALLANSON were elected to membership. Article IX of the by-laws was amended authorizing the executive committee to reinstate absentee, resigned, and expelled members.

Notes and reviews: C. L. SHEAR reviewed *Monographia Discomycetum Bohemiae*, by JOS. VELENOVSKY. (Praha 1934, 2 parts, text and plates.) This work includes 1471 species, of which 800 are new, with 40 new genera.

R. K. BEATTIE reviewed the forthcoming book on systematic botany being published in English and Siamese, by HILDA S. CUNNIFF.

Program: F. C. MEIER: *Spore collections in the atmosphere over the North Atlantic and Greenland made during the Lindbergh flight of 1932* (with lantern) —Published in full in Scientific Monthly, January 1935.

C. E. COTTAM: *Present status of the eelgrass disease along the Atlantic Coast of North America.*—Published in full as Wildlife Research & Management Leaflet BS-3, February 1935.

C. O. ERLANSON: *An adaptation of the moss, Tetraplodon for the dispersal of its spores by carrion flies.*

264TH MEETING

The 264th regular meeting was held in the Assembly Hall of the Cosmos Club, March 5, 1935, President DIEHL presiding; attendance 100. The following were elected to membership: E. G. BEINHART, H. W. BARRE, C. O. ERLANSON, RALPH M. LINDGREN, F. SIDNEY BEECHER, SABURO KATSURA, W. C. LOWDERMILK, F. L. MULFORD, HILDA S. CUNNIFF, MARGUERITE WILCOX, GUY E. YERKES.

Notes and reviews: J. B. S. NORTON reviewed the new edition of Webster's dictionary from the standpoint of its usefulness in strictly botanical work. M. C. MERRILL reviewed the latest number (Vol. 8) of the Transactions of the Bose Research Institute, Calcutta.

Program: ROBERT F. GRIGGS: *Dionaea's place in Nature* (with lantern).

A. S. HITCHCOCK: *The Grasses of the United States* (with lantern).—There are in the United States 159 genera and 1100 species of grasses. By means of slides about 40 species of grasses were shown, chosen to illustrate the advance in structure from the simple to the complex. The Bambuseae are regarded as the most primitive and the Andropogoneae the most complex, with Indian corn (*Zea mays*) the culmination of the series.—*Author's abstract.*

265TH MEETING

The 265th meeting consisted of the annual banquet and dance, held in the ball room of the Kennedy-Warren, April 2, 1935; attendance 187.

Program: WM. H. WESTON JR.: *Sex in the lower fungi.*

CHARLES F. SWINGLE, *Recording Secretary*

SCIENTIFIC NOTES AND NEWS

Prepared by Science Service

NOTES

Geological Survey.—L. M. PRINDLE has been engaged on an examination of the Enoree Purchase Unit for the Forest Service and is now undertaking a study of the saprolites or deeply rotted crystalline rocks of the gold belt in the Southern Appalachians, especially in Georgia. It is thought that a study of the heavy minerals in the saprolite will help direct the search for the most favorable gold-bearing localities. He has turned in for transmittal to the Forest Service reports on the Uharie Unit, N. C., as well as on the Enoree tract.

Soil Erosion.—All work aiming at the control of soil erosion has been consolidated in a new soil erosion unit established by order of Secretary of Agriculture HENRY A. WALLACE. Under-Secretary REXFORD G. TUGWELL has undertaken the administrative task of organizing the new unit, which is under the immediate direction of H. H. BENNETT. The consolidation affected the Soil Erosion Service, formerly under the Department of the Interior, and various phases of soil erosion investigation hitherto carried on by the Bureau of Chemistry and Soils, the Bureau of Agricultural Engineering and the Bureau of Plant Industry. Research will be conducted at ten field stations, and the large-scale demonstrations already in progress will be continued and extended.

Aviation Weather.—More detailed weather news for fliers, at slightly longer intervals, began on May 1. Observations, maps, and forecasts prepared by the U. S. Weather Bureau now go out every six hours, instead of every four hours as formerly, over the teletype circuit maintained by the Bureau of Air Commerce along the airways of the United States.

Each main airport station receives, every six hours, enough information for the preparation of a weather map of the whole United States, as well as the details of conditions in a wide area around it.

All pilot balloon observations have been advanced one hour, so that the six hour reports and the airplane observations may be received in time to be checked and analyzed for use in making the maps. Lengthening the periods of teletype transmission makes it possible to send over circuits west of Kansas City and Chicago full weather reports from ships in the Pacific and also permits some increase in reports from Canada and Mexico.

Department of Terrestrial Magnetism.—In order to expedite the transmission of scientific data between the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and its magnetic observatory at Watheroo, Western Australia, the Australian Government has recently authorized the installation at the observatory of an equipment of sufficient power for direct communication with Washington, D. C. The installation has been completed and communication established with radio stations at Washington Grove, Maryland (just outside of Washington) and Fresno, California. During periods when direct communications through Washington Grove is not possible, messages are relayed through the West-Coast station. Thus it is possible for scientific information obtained at Watheroo to be transmitted to Washington without delay and schedules are maintained for this purpose.

There have been received recently in Washington an extensive series of magnetic records, control-observations, absolute determinations at field stations in Antarctica during sledge trips, etc., successfully carried out by the Byrd Antarctic Expedition II, during the period February 1934 to February 1935.

New Non-Magnetic Ship.—A first instalment of 10,023 pounds, towards the construction by the British Admiralty of a non-magnetic vessel has been included in this year's Naval Estimates presented to the House of Commons on March 6. The purpose of this new vessel is to resume the ocean magnetic-survey work which was carried on by the CARNEGIE, under the auspices of the Carnegie Institution of Washington, before her destruction by explosion and fire on November 29, 1929, in harbor at Apia, Western Samoa.

The magnetic charts published by the British and other governments for use at sea have been based in recent years to an increasingly large extent upon data provided by the CARNEGIE. There are, however, serious gaps in the present data which would have been filled if the CARNEGIE had completed her last cruise. These gaps together with a recent rapid change in the secular variation in the Indian Ocean, render the extrapolated values of the magnetic elements in the southern Indian Ocean unreliable and indicate the possibility of serious errors in future charts of this and other ocean areas. Since the Carnegie Institution of Washington has decided not to replace the CARNEGIE, the British Government, in view of her large maritime interests, has assumed the responsibility. The details of the design of the new non-magnetic vessel, the primary purpose of which will be the determination of magnetic data at sea, have not yet been made public, though it is probable that the new vessel will be larger than the CARNEGIE.

National Park Service.—J. Thomas Schneider, at the special request of the Secretary of the Interior is working on legislation calling for the preservation of historic sites and buildings. Mr. Schneider recently made a survey of European historic sites.

Study of Maternal Care.—The Children's Bureau has completed what is expected to be the first of a series of studies of community provisions for maternal care. This first study, in Hartford, Conn., was undertaken at the invitation of the Hartford Medical Society, which appointed an advisory committee of five members for the study, representing also the local hospitals.

Data was obtained as to all deliveries of women resident in the city of Hartford that occurred during two periods of three months each—May, June and July, 1933, and January, February, and March, 1934, a total of about 1,200. The necessary information was obtained by means of interviews with the attending physician, by study of the hospital records, by reports from the visiting-nurse association, and by interviews with the mothers themselves three months or more after the delivery. These interviews were always obtained with the consent of the physicians attending the women.

The purpose of this series of studies is to ascertain: the type of maternal care received by an unselected series of mothers in different localities; and the proportion of these mothers having abnormalities or morbidity.

The results of the present study are now being analyzed in preparation for the writing of the report.

Paleontological Society.—The Paleontological Society of Washington was organized Wednesday evening, December 19, 1934, in the U. S. National Museum. The purpose of the Society is to promote a closer understanding between the fields of biology and paleontology; to offer opportunity for open, informal discussion of biological and paleontological theory; and to provide a suitable place for the presentation of original and technical papers of general interest to research workers in both of the fields of science.

The following officers were elected: Honorary President, DAVID WHITE (since deceased); President, CHARLES W. GILMORE; Vice-President, REMINGTON KELLOGG; Secretary, LLOYD G. HENBEST; Treasurer, G. ARTHUR COOPER; Member of the Council, S. F. BLAKE. Meetings are held the third Wednesday evening of each month. The programs at present are planned to include brief communications, reviews, etc.; regular papers; and to provide at least one-half of the time for informal discussion on a previously announced subject.

International Zoological Congress.—The Twelfth International Zoological Congress will be held in Lisbon, Portugal, under the patronage of the President of the Portuguese Republic from Sunday, September 15th to Saturday, September 21st, 1935. Sessions of the Congress will be held at the University of Lisbon under the presidency of Dr. A. RICARDO JORGE, Professor of the Faculty of Sciences of the University and Director of the Zoological and Anthropological Department of the National Museum of Natural History.

Field Conference of Pennsylvania Geologists.—The fifth annual meeting of the Field Conference of Pennsylvania Geologists will have its headquarters at the Academy of Natural Sciences in Philadelphia on Friday, May 31st–Sunday, June 2nd. Registration and museum tours will take place from 9 A.M. to 12 M. on Friday, May 31st, and at 2 P.M. the first of the trips will leave Philadelphia to observe the physiography of the Piedmont upland and the adjacent Coastal Plain terraces around Philadelphia. An alternative trip to localities of mineralogic and petrologic interest to the north of Philadelphia will also be conducted on that afternoon. On Saturday, June 1st, the Conference will leave the Academy at 8 A.M. on a general trip through the crystalline and intrusive rocks of the Piedmont Belt in the Philadelphia area. On Sunday, June 2nd, they will leave at the same time to examine the lower Paleozoic formations and their relations to the pre-Cambrian rocks in the area west of Philadelphia. This trip will go as far west as Quarreyville which is the type area of the Martic overthrust. On Monday, June 3rd, a post-Conference optional excursion to the Coastal Plain of New Jersey will be conducted.

NEWS BRIEFS

A Pan-American pact for the protection of art galleries and scientific museums during war was signed at the White House on April 15 by representatives of Bolivia, Brazil, Chile, the Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, the United States and Uruguay. By the terms of the pact, certain cultural buildings, sites and monuments, marked with a banner of peace, are to be considered neutral zones in time of war, and as such shall be immune from airplane bombing and other acts of hostility.

The National Zoological Park has received an allotment of $680,000 from PWA funds. It is planned to build an addition to the bird house, a new elephant house and a house for small mammals, with special accomodations for apes. It is also planned to provide a machine shop.

Two unusual meteorites, both seen to strike the earth in North Carolina, have just been received by the Smithsonian Institution, which will cooperate with the North Carolina State Museum in their analysis.

Personal Items

Dr. Nolan D. C. Lewis, director of laboratories at St. Elizabeth's Hospital, has been given leave of absence for the purpose of making a survey of existing research projects and methods of treatment and control of dementia praecox, as a preliminary step in a campaign against this disease financed by the Scottish Rite Masons of the northern jurisdiction of the United States.

The Remington Honor Medal, highest award in pharmacy, has been given for 1935 to Samuel Louis Hilton, retail pharmacist of this city, in recognition for his many years of service to his profession, and in particular for his efforts in connection with the building of the American Institute of Pharmacy, recently completed.